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JOHN L. RICH
EDITOR

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THE BULLETIN

of the

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JOHN L. RICH, *Editor*

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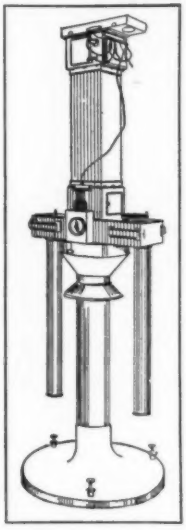

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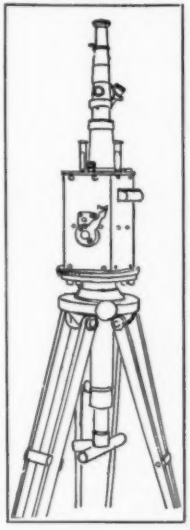

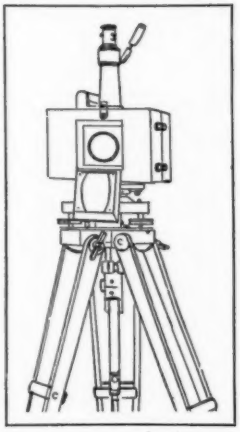

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CONTENTS

NEW DATA ON THE COMANCHEAN STRATA OF CENTRAL KANSAS . . . 553
By W. H. Twenhofel and A. C. Tester

METHODS OF CORRELATION BY MEANS OF FORAMINIFERA 562
By J. J. Galloway

FURTHER OBSERVATIONS ON SHOESTRING OIL POOLS OF EASTERN KANSAS 568
By John L. Rich

THE FORAMINIFERA OF THE VELASCO SHALE OF THE TAMPICO EMBAYMENT. 581
By Joseph A. Cushman

THE WOODBINE SAND OF TEXAS INTERPRETED AS A REGRESSIVE PHENOMENON 613
By Gayle Scott

LITHOLOGIC CHARACTER OF SHALE AS AN INDEX OF METAMORPHISM . 625
By John H. Wilson

GEOLOGICAL NOTES
Occurrence of Ordovician Sediments in Western Kansas, *Jon A. Udden* . . . 634

DISCUSSION
Early Pennsylvanian Sediments West of the Nemaha Granite Ridge, Kansas, *A. R. Denison* 636
Some Features of Red-Bed Bleaching, *F. H. Lahee* 636

REVIEWS
The Possibility of Oil in Western Ziebach County, *William L. Russell* (K. C. Heald) . 638

ROUND TABLE
Joint Meeting with the Rocky Mountain Section of the A.I.M.M.E. and American Mining Congress 640
Annual Meeting for 1927 to be Held in Tulsa 640

AT HOME AND ABROAD
Current News and Personal Items of the Profession 641

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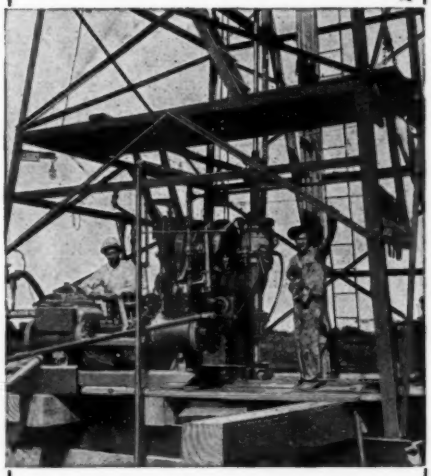

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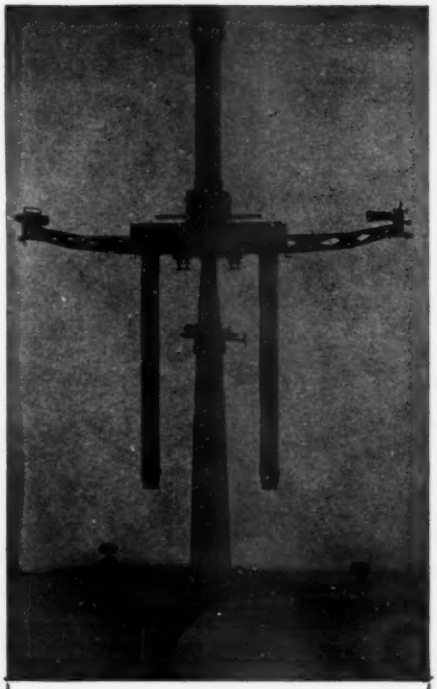

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JUNE 1926

NEW DATA ON THE COMANCHEAN STRATA OF CENTRAL KANSAS

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AND

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ABSTRACT

New stratigraphic sections and information on the distribution of the fossil-bearing members are offered. The writers conclude that (1) cone-in-cone always occurs with the Windom member, and rarely at any other stratigraphic position; (2) the interval between the two marine members of the Comanchean decreases eastward, southward, and westward; (3) the lithic character of the Mentor member varies greatly and the variation in the fauna is equally as great; (4) the Windom member is persistent lithologically, although the fauna varies considerably; and (5) because of the persistent distribution and position of the cone-in-cone layers they may be considered of much correlative value.

INTRODUCTION

During the summer of 1924 the senior writer re-examined the Comanchean strata of central Kansas and the junior writer studied independently the Comanchean and so-called "Dakota" formations of most of the state. Parts of the results of these studies are given in this paper.

A description of the Comanchean strata of Kansas, prepared in part several years ago, was published by the senior writer late in the summer of 1924.[1] In this paper the subdivisions of the strata were

[1] W. H. Twenhofel, "Geology and Invertebrate Paleontology of the Comanchean and 'Dakota' Formations of Kansas," *Kansas Geol. Survey Bulletin* 9 (1924), p. 135.

Read before the Wichita meeting of the Association, March 26, 1925; manuscript received by the Editor April 26, 1926.

based on the exposures in the vicinity of the "Natural Corral" in the NW. ¼, Sec. 5, T. 18 S., R. 5 W., McPherson County, about 6 miles southwest of Marquette, at this time the only known fairly complete section. The only other exposure known at that time which shows a horizon containing fossils, and some of the associated strata, is near Brookville. The work in 1924 has shown that there are several other places in which considerable portions of the Comanchean strata are exposed, and these discoveries render advisable several modifications of the views previously advanced.

Through the kindness of Mr. G. Dallas Hanna, of San Francisco, attention has been called to the fact that two, and perhaps three, of the new species described in the publication just mentioned, have been given names previously used. This opportunity is taken of applying new names to two of these species. For the opportunity of studying these strata the senior writer is indebted to Mr. B. E. LaDow, of Fredonia, Kansas, and the junior writer, to Dr. R. C. Moore, of the Kansas Geological Survey.

DESCRIPTION OF THE SECTIONS

For purposes of comparison the description of the Natural Corral section is given, as it still represents the most extensive and complete section of the central Kansas Comanchean so far discovered. It is composite and is given on page 555.

In the northeast quarter of the section in which the Natural Corral is situated, 9 feet of light blue-gray clay overlie the Mentor sandstone. This is overlain in apparent conformity by the "Dakota" sandstone. To the west of the Natural Corral, in Section 6 of the same township, the Mentor sandstone gradually thins, the overlying clay appears in varying thickness, and the basal portion of the "Dakota" sandstone increases in thickness. About 3 miles west of the Natural Corral the Mentor member is absent entirely and the highly crossbedded "Dakota" sandstone rests on an erosion surface which crosses zones 7, 8, and 9 of the Natural Corral section. Drab-colored clays are associated and interbedded with the "Dakota" sandstone.

In the SW. ¼ of Sec. 32, T. 19 S., R. 6 W., 4 miles south of the village of Little River, the base of the Comanchean is exposed in

contact with the Wellington (?) formation of the Permian. The basal bed of the Comanchean is a coarse pebble conglomerate overlain by coarse-grained light-buff sandstone. Overlying this are 22 feet of black carbonaceous shale which, except near the top, weathers to light-gray papery fragments. The top strata are sandy and weather to a brownish color. Capping the shale is a reddish-brown limestone

SECTION OF COMANCHEAN STRATA AT NATURAL CORRAL, PcPHERSON COUNTY

	Thickness (Feet)
12. "*Dakota*" sandstone.	
Mentor member	
11. Sandstone, red, concretionary and cross-laminated; rather coarse grained. Mentor fossils occur 4 to 6 feet from the top	8
Marquette member	
10. Sandstone, yellow, medium grained, friable and cross-laminated	2
9. Sandstone, yellow, fine-grained, friable, and cross-laminated	17½
8. Sandstone, yellow and white, fine-grained and compact	7–8
7. Shale, blue, thin-laminated	10
6. Sandstone, yellow, contains dicotyledonous leaves	2
5. Shale, blue, gypsiferous	14
Windom member	
4. Limestone, gray, composed almost entirely of shells. Two 6-inch beds separated by gray shale	3
Natural Corral member	
3. Shale, dark blue, gypsiferous, contains calcite cone-in-cone near top	16
2. Concealed	14
Permian	
1. Wellington shale (exposed)	25

which is 8 to 12 inches thick and composed almost entirely of *Ostrea* shells and fragments. Above this are exposed 20 feet of gray and brown fissile shale, of which the upper portion locally contains thin lenses of sandstone or very sandy shale. Cone-in-cone occurs in the lower part of this zone. The limestone and cone-in-cone layers constitute the Windom member.

On the east side of Sec. 7, T. 20 S., R. 6 W., about a half-mile south of the so-called Bush or Hilltop well, two shell limestones are exposed in the road ditch. The lower limestone is about a foot thick and has a cone-in-cone layer just above it. This is considered to be the Windom member. The upper limestone, probably equivalent to

the Mentor member, is 18 to 19 feet higher and appears to be 3 to 4 feet thick, but as there has been some slumping, the exact thickness may be less than that given. Cone-in-cone is also associated with this limestone. Poorly exposed shale occupies the interval between the two linestone beds. In each bed of limestone oyster shells are about all that are present and the rocks are essentially coquinas.

In Sec. 1, T. 20 S., R. 7 W., about 1½ miles northwest of the Bush well, what appears to be the equivalent of the upper limestone is exposed in the bed of a creek. However, it does not bear the slightest resemblance to the rock on the east side of Section 7, although the elevation indicates that it is the same. The rock is a hematitic fine-grained sandstone in the midst of unfossiliferous gray shale. The sandstone contains patches of shells of Mentor aspect. One-fourth of a mile east, oyster-shell beds hold the stratigraphic position of this sandstone.

Six miles west and 2 miles south of the above-mentioned locality (about 3½ miles southeast of Lyons) in the SW. ¼ of Sec. 7, T. 20 S., R. 7 W., a 4- to 5-inch medium-grained hematitic and concretionary sandstone is exposed in a road ditch and contains a meager fauna of small pelecypods and a few gastropods of Mentor type. It is not possible to trace this bed continuously to a more complete section, and although it occurs about 50 feet higher than the Mentor of Section 1 in the same township, the presence of the Mentor fauna and the association with gray and brown shale indicates that the correlation probably is correct. The difference in elevation is probably due to the small northeast regional dip of the Comanchean strata.

A little west of the "Rocks" or "Cave," about 2 miles west of the town of Little River, on the east side of Sec. 14, T. 19 S., R. 7 W., in the creek bank south of the Santa Fe Railroad, a very good section of these strata with two fossiliferous horizons is exposed. From the summit downward the section is as follows:

At the "Rocks" the "Dakota" descends to a level below that of the creek and below the lower fossiliferous member of the above section.

About 1½ miles north of this locality the Mentor horizon is exposed on one side of a little valley. It consists of 3 feet of oyster-

shell limestone, and overlies gray shale. On the opposite side of this valley, not more than 100 feet distant, the strata are fully exposed, but there is no trace of the shell bed. Traced northward along the side of the valley the shell bed changes to a red sandstone containing an occasional Mentor fossil.

Approximately three-fourths of a mile north of Langley, in Ellsworth County, about 15 feet of dark shale are exposed, in whose lower portion are two cone-in-cone layers. The upper layer is about 4 inches thick, and the lower, 8 to 10 inches thick. The Windom shell bed—here not made up of oysters—is 4 to 6 inches thick and lies between the two cone-in-cone layers.

COMANCHEAN STRATA WEST OF LITTLE RIVER, RICE COUNTY

	Thickness (Feet)
5. *"Dakota"*	
4. *Mentor member* Sandstone, red, medium-grained, and cross-laminated. Has typical Mentor aspect and contains Mentor fossils	5–6
3. Sandstone, yellow, fairly well bedded. No fossils found	3
2. Shale, gray-blue and dark, containing thin beds of sandstone; crystals of selenite common, pyrite nodules present	15
1. Shale, dark gray and thin-laminated; contains pyrite nodules, many thin calcareous sandstone and limestone lenses, and a cone-in-cone layer. The limestone beds contain pelecypod shells other than those of oysters. The sandstones also are fossiliferous, and often contain glauconite and pyrite	2

On Bluff creek, in Sec. 5, T. 17 S., R. 6 W., about 5 miles northwest of Langley and 6½ miles northeast of Crawford, a little more than 50 feet of Comanchean shale and thin sandstone lenses are exposed. These rest directly on the Permian. Two distinct cone-in-cone layers are present, one 8- to 10-inch bed about 11 feet above the Permian and a 5- to 6-inch bed 30 feet higher, the interval being occupied by gray fissile and brown sandy shale. The fossiliferous limestones or sandstones were not seen and it is doubtful if they occur. The Comanchean shale is succeeded upward by cross-bedded sandstone and gray clay which are assigned to the "Dakota," although the sandstone beds locally resemble those of the Mentor. The "Dakota" sandstone caps the upland east of Bluff Creek and extends south toward Crawford.

In Sec. 33, T. 15 S., R. 7 W., about 2½ miles east of Kanopolis, on the east side of Smoky Hill River, a fairly complete section of the Comanchean strata is exposed.

COMANCHEAN STRATA EAST OF KANOPOLIS, ELLSWORTH COUNTY

	Thickness (Feet)
7. Sandstone, gray, fine to medium grained; usually in massive beds, making principal ledge of bluff; variously cross-bedded. The member is essentially calcareous, though considerable silicification has occurred in the upper part. In many respects this sandstone resembles some phases of the Mentor of the Salina region, and is considered to be the equivalent of the Mentor	6–7
6. Shale and sandstone, mostly gray and fine grained	2–3
5. Sandstone, gray, fine grained, and evenly bedded; usually a single massive bed. Contains locally much pyrite and an occasional "charcoal" or lignite fragment	3–4
4. Shale and sandstone, the latter in very irregular lenses. The shale is gray-black, fissile, and contains a cone-in-cone horizon of irregular thickness. The sandstone is gray and fine grained	9–10
3. Shale, black and carbonaceous, thinly bedded, much oxidized pyrite and selenite on surface; grades upward into a more sandy phase, though retaining the carbonaceous material; grades into zone 4	16
2. Sandstone and shale. A gray, fine grained sandstone layer at top and bottom separated by 1½ feet of irregularly bedded shale and sand containing a well developed cone-in-cone horizon. In part the cone-in-cone is developed around red sand concretions and in part as a single layer, both of which occur at the same horizon	3–4
1. Shale, dark-gray to black, carbonaceous and fissile. Contains many small selenite crystals and poorly preserved imprints of small pelecypods, not oysters. In upper part grades to lighter gray and more sandy phases (exposed)	21

This section is overlain by sandstones which are assigned to the "Dakota." One-half mile south the base of the "Dakota" is at river-level, 60 feet lower, the result of the cutting out of the Comanchean strata before the deposition of the "Dakota."

A second section of similar nature may be seen about 2½ miles southeast, on the east side of Smoky Hill River, but since the "Dakota" lies at a lower level, not as much of the Comanchean is shown.

On the east bank of a creek about 3 miles west and 4 miles north

of Marquette the lower shell bed, or Windom member, is exposed in the midst of about 10 feet of dark shale, a cone-in-cone layer being associated with the shells. The fossils in the shell bed are small and are different from those seen elsewhere. This shale zone may be traced east and south for several miles, but the shell bed is not always present.

In a section exposed along Solomon River near the power plant about 2 miles south of Bennington, gray-black fissile shale like that of the Comanchean and containing cone-in-cone may be seen, but the Windom shell member seems to be absent.

Many other small exposures of the Windom member in Rice, McPherson, and Saline counties show the close association of the cone-in-cone zone. The presence of the fossiliferous Windom member is almost always accompanied by the cone-in-cone zone, but the cone-in-cone layer is often found in the dark-blue shale at the proper stratigraphic position, but without the shell layer.

SUMMARY

From the foregoing descriptions there stand out four important facts:

1. A cone-in-cone layer occurs everywhere in association with the Windom member, and at one place it has been seen in connection with the Mentor member. No exposure of the Windom member has been found in which cone-in-cone is not associated and, excepting the one occurrence with the Mentor member, it has not elsewhere been seen at other stratigraphic horizons. Because of this limited occurrence it is considered that cone-in-cone has considerable correlative value.

2. The interval between the two marine members varies from 53 feet at Natural Corral to about 15 to 16 feet in eastern Rice County, the thinning being at the expense of the sandstone units of the Marquette member. Apparently these sandstones are of very local distribution.

3. The character of the Mentor member varies greatly from place to place, and with the lithic variations are faunal variations of equal significance. In places it is an oyster coquina, as at several localities south of Little River; in others, limestone filled with a

variety of shells; in others, sandstones of varied character with or without fossils, as at Natural Corral, near Falun, south of Brookville and Bavaria and east of Mentor. Especially good examples of the variation may be seen on the east side of Smoky Hill River southeast of Salina and east of the village of Mentor. In Sec. 22, T. 15 S., R. 2 W., 3½ miles east of Mentor, 4 to 5 feet of hematitic coarse sandstone with large numbers of pelecypods, not oysters, and many gastropods represent the Mentor bed, while 1½ miles south, in Sec. 27, at the same horizon, are 3 to 4 feet of calcareous and siliceous sandstone in which the fossils are almost entirely oysters and iron oxide is essentially absent. A similar condition occurs locally near Iron Mound, just southeast of Salina, and again northeast of that town on the north side of Saline River.

There are also places where the strata of the Mentor horizon appear either not to have been deposited, or to have been deposited and removed before the deposition of the overlying "Dakota." One such place of removal appears to be at "The Rocks," near Little River, where the sandstones of post-Mentor aspect descend to below the level of the Mentor and even the Windom member. Another example of such a condition may be seen southeast of Kanopolis, along Smoky Hill River, as described above.

4. The Windom horizon has a calcareous lithology wherever observed. The fauna shows considerable variation, in some places being composed of oysters, and in others, of a variety of species. The Windom member does not appear to extend as far north as does the Mentor member.

DISTRIBUTION OF THE COMANCHEAN STRATA

The map given in *Bulletin 9* of the Kansas Geological Survey is correct in general for central Kansas, but errs in detail. In eastern Rice and Ellsworth counties the belt is generally wider than indicated, and in eastern Rice county a belt of Permian limestone projects from the south northward along Little Arkansas River up to Little River, so that the Comanchean is divided. In Rice County, Comanchean strata may be found as far west as 2½ miles southeast of Lyons. It is very probable that Comanchean strata also occur along Cow Creek, west of Lyons, but they have not been seen.

Roughly, it may be stated that east of the center of Range 7, in Rice County, the surface strata are for the most part composed of Comanchean. In the extreme southeastern corner this may not hold, as alluvium covers the surface and the Comanchean may have been eroded away.

The base of the Smoky Hill Buttes and the ridge of hills south of Salina and east of Smoky Hill River are certainly composed of Comanchean strata. The evidence of distribution in north Saline County is less definite, but the occurrence of the cone-in-cone layers on the hilltop north of Salina and along Solomon River south of Bennington indicates the presence of the Comanchean in that locality. It is very probable that some Comanchean strata—possibly marine—hitherto called "Dakota" extend to and beyond the Nebraska line.

TOP OF THE COMANCHEAN STRATA

It is difficult to determine just where should be drawn the line separating the Comanchean strata from the "Dakota." Perhaps it is unwise to attempt to draw such a line. At any rate that is not the purpose of this paper, and it seems best to await the determination of the position of the strata which in Kansas are generally known as the "Dakota."

RENAMING OF SPECIES

In *Bulletin 9* of the Kansas Geological Survey a species from the Mentor beds was named *Cucullaea (?) gigantea*. It is not certain that the generic reference is correct, but at any rate the specific name has been previously used for a form of *Cucullaea*,[1] and it seems desirable that the name be changed. It is hence renamed *Cucullaea (?) herculea*.

Another species was named *Leda acuminata*. This name previously has been used for two other species of this genus. The new species is here named *Leda smolanense*.

It is possible that *Corbicula elongata* may conflict with *Cyclas elongata*, but until more definite information on this score is available it seems best to let the name stand.

[1] Conrad, *Journal of the Academy of Natural Science*, Vol. 6 (Philadelphia, 1830), p. 227.

METHODS OF CORRELATION BY MEANS OF FORAMINIFERA

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ABSTRACT

The determined principles of paleontologic correlation are applied to the use of Foraminifera for age determination and horizon identification and the relative values of the different criteria are briefly considered in this paper.

There are, in general, four cases in which correlation is desired: (1) Correlation between continents, wherein it is desired to determine the period or epoch of the standard time scale to which a formation belongs; (2) correlation between different stratigraphic provinces in the same continent; (3) correlation in the same stratigraphic province, wherein it is desired to determine to what formation in a local standard a formation belongs; and (4) correlation of horizons in a small area, as an oil pool, to determine the exact equivalency or identity of horizons.

Each of the above cases requires the application of criteria appropriate to the problem, and different for the different cases.

There are two classes of criteria which are applied to correlation: (1) inorganic, and (2) paleontologic. Inorganic criteria are almost valueless in intercontinental correlation, becoming increasingly dependable as the distance between formations correlated decreases. In quadrangles of one-half a degree on a side, lithology, thickness of beds, and superposition are the handiest and most frequently used criteria.

Paleontologic criteria are necessary for intercontinental correlation, but they reach their maximum usefulness in the same stratigraphic province. In an oil structure where wells pass through many thin and different beds, as in the Pennsylvanian of Kansas, inorganic criteria are nearly or quite as useful as fossils for indentification of beds. Where nearby wells pass through thick and only slightly different beds, as in the Pliocene of California, then organic

criteria must be used, and when fossils are numerous and the paleontological criteria are properly applied, the resulting correlation can be depended upon.

There are at least eight different paleontologic criteria for correlation, in increasing exactness, as follows: (1) general faunal aspect, or like genera; (2) evolutional stages of faunas, or homologous species; (3) abundance of specimens of a genus or species; (4) percentage of like species; (5) percentage of like species represented by abundant specimens; (6) sequence of faunas; (7) index genera and species; (8) guide fossils or subordinate mutations of complex organisms. Each of these criteria will be briefly considered.

1. *General faunal aspect.*—The presence of several genera is sometimes sufficient to determine the geologic period to which the fauna belongs, as the presence of *Planularia*, *Robulus*, *Epistomina*, and *Psammophis* indicates Jurassic; or *Placopsilina*, *Heterostegina*, *Guembilina*, and *Globigerina* indicates Cretaceous. This criterion is useful in reconnaissance, but gives place to more refined methods in the laboratory. When the genera are known to be confined to a single system they pass to the grade of index fossils.

2. *Evolutional stages, or homologous species.*—Sometimes correlations can be made between continents or disconnected stratigraphic provinces by means of comparison of similar species which have evolved from the same stock, as is frequently done with mega-fossils. The similarity, for instance, of *Cycloloculina annulata* to *C. eocaena* would indicate that the age of *C. annulata*, whose age cannot be arrived at in any other way, is Eocene. This criterion is used only when all others fail. It can scarcely be used yet with Foraminifera, because homologous species have usually been misidentified, being considered only as chance variants of some familiar form, in which case they are not figured.

3. *Abundance of specimens of a genus or species.*—Identification of a period can be made on mere abundance. For instance, the presence of abundant specimens of *Nummulites* in the Zona Sala limestone of Chiapas proves that the formation is of Eocene age, for although Nummulites ranges from the Pennsylvanian to the later Tertiary, it occurs in abundance in many places in the world only in the Eocene. *Guembelina globulosa* ranges from Jurassic to Pliocene,

but occurs in immense numbers only in the Upper Cretaceous. Hence the mere presence in abundance of that species is sufficient to determine its age. *Uvigerina* and *Amphistegina* occur in abundance together in the Miocene. Large numbers of *Cassidulina* indicates Pliocene, abundant *Endothyra* indicate Mississippian, and abundant *Frondicularia* indicate Cretaceous, although none of the genera are confined to the system indicated. Stratigraphic zones are frequently indicated by the genus occurring abundantly in the zone, as the "*Discorbis* zone" or "*Heterostegina* zone" of the Middle Oligocene of the Gulf Coast.

4. *Percentage of like species.*—This criterion is considered by most paleontologists to be the ultimate criterion for detailed correlation. The method breaks down, however, when we are dealing with long-lived and hardy species, in which case a high percentage of like species can be gotten from formations far apart in time. A large number of Pennsylvanian mega-fossils have such a long range that we may have 60 or 80 per cent of like species in formations separated by thousands of feet of sediments. Lists of species of Foraminifera cannot be compared unless the lists are made by the same person, or persons who are very critical in the names used for species. It has been the unfortunate practice of the English school of students of Foraminifera to lump all manners of diverse forms together, so that their lists are useless for comparison. Many present workers have insufficient literature, so that their lists of species are intelligible only to themselves. In time, with the critical study of American Foraminiferal faunas and the publication of figures, this situation will be remedied.

Even where species are critically identified, the method of correlating with a formation having the greatest number of like species is open to serious question. For example, last year S. G. Wissler and the writer divided a single sample of Del Rio clay from Austin. He identified twenty-four species and the writer, thirty species, each identifying all species present and comparing with each other's. There were, all together, thirty-seven species, and only seventeen species common to both samples. That is to say, in different halves of the same sample there were only 46 per cent of like species. There are faunas which are of the same age but have no species in common.

Differences in habitat, as well as difference in time, cause the faunas to be different. Provincial faunas are difficult to correlate with others of different provinces even of precisely the same age, but they have no disadvantage when correlating in the same province.

5. *Percentage of like species occurring abundantly.*—The rare species are of little value in correlation, for the simple reason that they are not always found. In the foregoing example from the Del Rio all of the ten species represented by numerous individuals were found in both halves of the sample, and only seven species of the rare ones were found in both; twenty rare species were not found in both. The frequently occurring species make 60 per cent of the like species, or, 100 per cent of frequent species occurred in both parts of the sample.

Correlation by comparison of the relative numbers of frequent species is not only more accurate than comparing the whole fauna, but it is much more rapid. The rare forms constitute the major part of most faunas, and are harder to identify than the more abundant species because the small number of specimens for comparison makes it impossible to judge individual differences. The rare forms can be disregarded except where they have been found to be index or guide fossils. Then any rare species is considered apart from its share in the percentage of like forms.

It is always best to consider the frequency of specimens of a species as of as much value as its presence. If ten species occur in a certain order in proportion of specimens present, and in another sample the same ten occur in the same order, the faunas may be regarded as identical, regardless of the rest of the fauna, except for index or guide fossils.

6. *Sequence of faunas.*—When two or more faunas are found in succeeding horizons and can be compared with other like sequences, there is a great probability of the identity of the sequences. Wherever possible, identifications of horizons, by whatever method, should be checked with corresponding faunas above and below.

7. *Index genera and species.*—Index fossils are those whose ranges and abundance are known, such as *Fusulina* for Pennsylvanian and Permian, *Neoschwagerina* for Uralian and Lower Permian, *Epistomina* for Jurassic, *Orbitoides* for Cretaceous, *Chilostomella* for Eo-

cene, abundant *Lepidocyclina* for Oligocene, abundant *Amphistigina* for Miocene, abundant *Cassidulina* for Pliocene, and most Astrorhizidae for Recent. Eventually large numbers of genera and species will become index fossils when their ranges are determined. Index fossils must be used with caution, for we may not have all the facts regarding their range and abundance. Where possible, the correlation should be checked by all the other means available.

8. *Guide fossils.*—These are fossils which are known to have a restricted range and which occur frequently. They are the *ne plus ultra* of criteria for correlation and identification of horizons. So far there are only a small number of widely known species of Foraminifera which are guide fossils, though every worker has several of his own. Well-known guide fossils are *Endothyra baileyi*, Mississippian; *Schwagerina princeps*, Uralian; *Sumatrina*, upper Permian; *Pseudotextularia*, Upper Cretaceous; *Hantkenina*, Eocene; *Nummulites planulatus*, Middle Eocene; *Lepidocyclina mexicana*, Meson; *Amphistegina hauerina*, Miocene; and *Globigerina pachyderma*, cold water, Pliocene to Recent. In Europe the whole geologic column is divided into fossil zones and each indicated by its guide fossil. This method will come into greater use in North America and other continents as the guide fossils are determined.

For long-distance correlation, index fossils are the most reliable, as they are for separate provinces. For correlation in the same province, guide fossils, index fossils, and identity of several species are satisfactory. For identification of horizons in a small area special care must be taken and a local standard is necessary. For a standard it is best to identify the species and determine the relative abundance of species from top to bottom of a control well. Here we know that all the species may range through the whole depth of the well, as they do in the Pliocene of California for over 7,000 feet. Knowledge of the local range and variation in abundance is secured from the control well. In correlating in such cases we expect absolute identity of species and in the same relative abundance. In practice we learn to recognize different horizons by a comparison of a few of the most abundant species, not altogether ignoring the rare ones, and look for guide species. In such cases percentage of common species is not very reliable.

A standard can be obtained by finding a nearly complete column at the surface, but this is not so easy or reliable as a well section taken by standard tools or a core drill. Where identification must be rapid, as in oil work, the best method is to learn the index and guide fossils from a control well. Without a control well fromwhich the facts are first determined, identification of horizons by Foraminifera is no better than by lithology.

On the whole, Foraminifera are just as reliable as Mollusca or any other marine fossils for correlation. And this applies to the smaller as well as the larger Foraminifera. Foraminifera have the additional advantage of occurring in larger numbers, both as to species and specimens, than any other kind of fossils; they are not broken in drilling; and they can mostly be identified from the outside. Foraminifera, when closely discriminated, are at least equal to any kinds of fossils in ease of identification and certainty in correlation.

FURTHER OBSERVATIONS ON SHOESTRING OIL POOLS OF EASTERN KANSAS[1]

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ABSTRACT

Recent developments in the "shoestring" sand territory of Anderson and Linn counties, Kansas, by opening new pools and extending others, have thrown new light on the problems of the origin of these interesting sand bodies and of the accumulation of oil in them. The "shoestring" oil sands herein described lie at or close below the top of the Cherokee shale. They occupy gently winding channels cut sharply to a depth of about 50 feet into that shale. The available evidence leads to the belief that the channels were cut by streams during a slight uplift of the Cherokee sea bottom and were later silted up. The pattern of the channels as now known suggests that they are parts of a related drainage system which may ultimately be connected. The course of one of the channels is so related to the regional dip that the sand body forms a closed anticlinal trap independent of local structure. Certain of the sand bodies have been proved to extend beyond the area which is productive. The former presence of water in the sands, its relation to the present non-productive parts of the channels, and the influence of its withdrawal on the size of the oil pools and on the degree of saturation of the sands are briefly considered.

INTRODUCTION

Since the preparation of an earlier paper on the "Shoestring Sands of Eastern Kansas,"[2] some of the pools there described have been extended and a number of new ones opened. This new work has thrown additional light on the nature and origin of the sand bodies and on the problem of oil accumulation in them. The opening of new pools and extension of old ones has given a wider view of the problem of distribution of such "shoestring" sand bodies and has led to the suggestion that they are all parts of a related system.

This paper deals only with those pools of Anderson and Linn counties that lie at one horizon whose top is at or within 30 feet below the top of the Cherokee shale, which is the lowest formation of the Pennsylvanian system in this locality.

The principal shoestring pools at the horizon under consideration

[1] Read before the Association, Wichita, meeting, March, 1925; manuscript completed and revised to date, April 5, 1926.

[2] John L. Rich, "Shoestring Sands of Eastern Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 7 (1923), pp. 103–13.

are shown on the accompanying map, Figure 1. Of these, the Centerville string has not been extended since the publication of the earlier paper; the Goodrich-Parker string and the West Centerville string were partly developed at that time, but were not described in

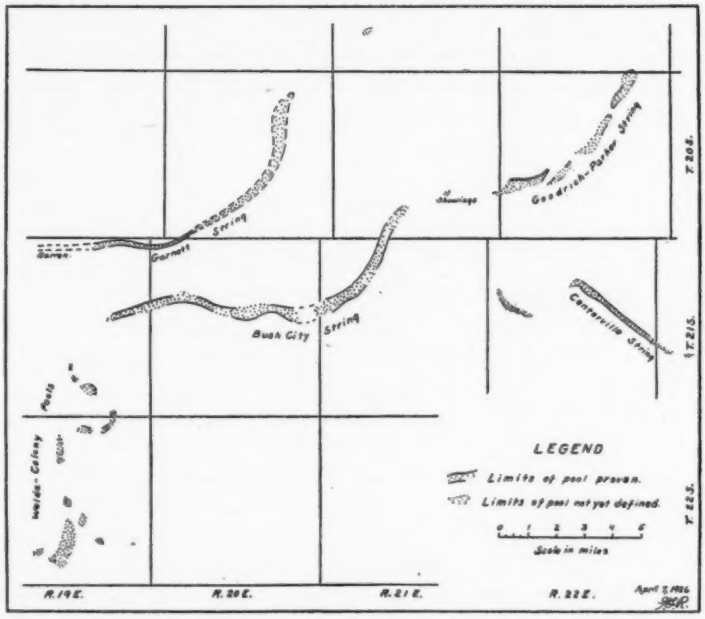

FIG. 1.—Shoestring oil and gas pools of Anderson and Linn counties, Kansas, Garnett sand horizon at or near top of the Cherokee shales. Acknowledgment is made to J. M. Lilligren, Edgar U. Owen, Scott Tarbell, and the Southwestern Petroleum Company for information used in compiling this map.

that paper; the Garnett string, as a producing oil pool, has been extended 2 miles to the west and the sand, with full thickness but carrying very little oil, has been traced for 2 miles farther; and the scattered pools and fragments of "shoestrings" between Welda and Colony, which for convenience we may call the Welda-Colony pools, were beginning to be developed when the earlier paper was written, but have since been extended. The Bush City string is recently discovered and is being actively extended at the east end. At

the west end the limits of the pool appear to have been reached where the oil becomes heavy and the saturation poor.

In all of these pools the sands lie at the same horizon. Except in certain of the Welda-Colony pools, all of these sands appear to be channel deposits of a type which will be more fully described in following paragraphs. In some of the Welda-Colony pools, especially at the south, Messrs. Edgar W. Owen and Homer Charles, who have made detailed subsurface studies of those pools, report that the sand bodies are irregular, comparatively widespread, and mainly of the bar rather than the channel type.

THE BUSH CITY STRING

The discovery well of the Bush City string was drilled in March, 1923, in the SE. corner NE. ¼ Sec. 15, T. 21 S., R. 20 E. Since then the string has been extended 5½ miles westward and 6 miles eastward, giving a total length to date of 11½ miles. The depth of the bottom of the sand varies from about 640 feet at the east to 840 feet at the west end.

Pattern.—As will be seen from the map (Fig. 1) the Bush City string has a general east-west course for 8 miles, and a northeast course for 3½ miles at the east end. It swings in broad curves of 2–4 miles amplitude. The curves are similar to those of the distributaries on a delta and also of certain types of streams on land recently uplifted. They are distinctly stream curves but are not of the meander type. These curves are responsible for many dry holes and for difficulty in extending the field, for the tendency of the operators is always to determine the trend of the pool and then to assume that it will continue straight. An understanding of the patterns and amplitude of these curves proves useful in projecting ahead the probable course of the sand body.

The sand body.—Cross-sections of the sand body (Fig. 2) show that it fills a channel cut sharply to a depth of about 50 feet into the marine blue shales of the Cherokee formation.[1] Typical logs show

[1] It is suggested that the horizon of the "shoestring" channels probably represents the true top of the Cherokee formation. The cutting of the channels apparently followed an uplift of the Cherokee sea floor and its exposure to stream action. This episode is a more logical division point between formations than the change from shale to limestone which takes place about 30 feet higher in the section and is ordinarily considered to mark the top of the Cherokee.

that the channel filling consists of 5–10 feet of black, somewhat shaly, pyritiferous sand at the bottom; above this, about 20 feet of relatively clean, fine-grained sand which carries most of the oil; above this, 10–15 feet of shaly oil sand of doubtful value; and, at the top, 5–15 feet of white, micaceous, talc-like shale which is locally sandy.

The black sand at the bottom appears to be a product of the reworking of a bed of dark, pyritiferous sandy shale in the Cherokee

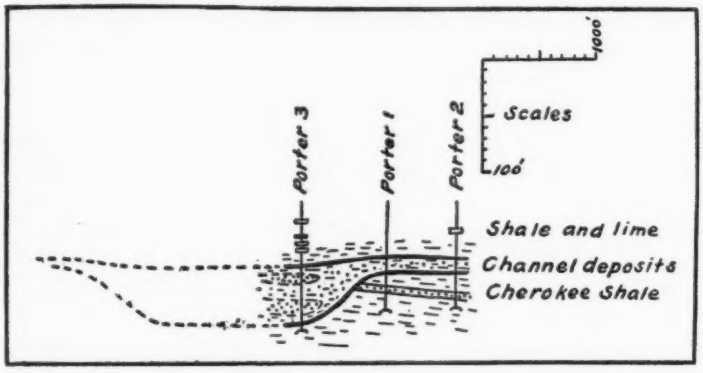

Fig. 2.—Typical cross-section of Bush City shoestring in Sec. 13, T. 21 S., R. 19 E., showing channel and its relation to the Cherokee shales. Right half of section drawn to scale from logs of wells; left half inferred from logs of nearby wells and from observations on other parts of the string.

formation which is cut by the channel about 20 feet above its bottom.

Dry holes at the edges of the channel encounter more or less of the white shale which marks the top of the channel deposit at the same level as that at which it is found in nearby producing wells, but go out of it directly into the blue Cherokee shale without striking any sand. Edge wells find white shale at the proper depth but pass out of the channel deposits into the blue Cherokee shale before reaching the depth of the bottom of the channel in neighboring wells. It is commonly reported, though the writer cannot verify the report from his own experience, that wells at a considerable distance from the string fail to find even the white shale. Among local operators,

the finding of the white shale at the proper horizon is considered an indication that the test is near the string, even though no sand is found below it.

The relations above described between the productive sand and the blue shale of the Cherokee show clearly that the sand fills a channel cut sharply into the Cherokee. There is no gradation from the channel type of sediments to the blue shale. The change is abrupt.

Within the channel the sequence of formations described above is almost always found, but in no two wells are the proportions the same. The clean "pay" sand appears to lie in lenses or stringers irregularly distributed within the channel. As a result, it is common for adjacent wells to vary widely in productivity. Such irregularity of the pay lenses is what might be expected in deposits formed in stream channels. The only guide to the location of the best bodies of sand which has been noted is that on the outsides of the bends, close to the bank of the channel, the sand is likely to be better than elsewhere. It is not uncommon for one of the best wells on a property, with 50 feet of channel deposits, to be located only 300 feet from a dry hole at the edge of the channel.

As has already been stated, the upper part of the channel filling is generally shaly. Several diamond drill and other core tests of these sands have shown that minute lamination and cross-bedding of sand and shale is the prevalent condition in this part of the sand body. In some instances the entire thickness of the producing sand is thus laminated. In one well from which the writer saw a core, the "pay" had a thickness of about 18 feet, but the core showed that about three-fourths of this was shale and none of the pure sand beds exceeded 18 inches in thickness, and few of them were more than 3 inches thick. Wells in such "sands" give a flush production of 10–20 barrels after a shot, but this quickly falls to 2 or 3 barrels per day.

Saturation.—Core drilling of the Bush City and other pools at this horizon has shown that a very low degree of saturation of the sand is common. Where a core is available, the approximate degree of saturation of the sand can readily be determined if the core is examined immediately after being taken out. Such an estimate is much more difficult where only cuttings from a churn drill are

available; but after the experience of coring poorly saturated sands in other pools and after careful watch of the drilling and examination of fresh cuttings from the Bush City field, the writer is convinced that poor saturation is a common condition in this field. Slow bleeding as the upper parts of the sand are drilled; lack of noticeable bleeding from the larger fragments of the drill cuttings; and the presence of "dead oil" scum in the bailings, all point to the same conclusion.

In general, the degree of saturation appears to vary irregularly from place to place as if, in an irregularly lenticular sand, some of the lenses had been drained of most of their oil while others retained it.

At the west end of the string, evidence to date indicates that the sand body continues beyond the present limits of the oil pool, but it carries only a very slight showing of oil. At the west end of the productive part of the string, in Sec. 14, T. 21 S., R. 19 E., the oil becomes very heavy, grading from 35° Bé. in the W. ½ Sec. 13 to 20° Bé., or less, in the center of Sec. 14. A well drilled 500 feet south and 320 feet west of the center of Sec. 14, found the channel sand of full depth with only a smell of oil. The sand was partly cemented. A mile farther southwest, a well, which may be on a continuation of the Bush City string, struck about 40 feet of sand at the Bush City horizon, but it carried only a very light showing of oil.

The reason for this condition at the west end of the string is unknown, but, as will be suggested in a following paragraph, it may be related to a former water level in the sand.

Lack of water.—No water is now found in the sand in any part of the Bush City string. It is customary to drill the wells through the sand and about 5 feet into the Cherokee shale below. At an earlier stage in the physiographic history of the region, water may have been present in the parts of the sand not then filled with oil.

Relation to structure.—Beginning at its west end in Sec. 14, T. 21 S., R. 19 E., the course of the Bush City string with reference to structure and regional dip is as follows: For the first mile, across Sec. 13, the string lies nearly flat; thence eastward to the E. ½ Sec. 15, T. 21 S., R. 20 E., where the string crosses a local high, it rises with the regional dip about 12 feet per mile; thence it drops slightly eastward for about a mile, to the bottom of a shallow syncline from

which it rises rather steeply eastward to a point at the east line of R. 20 E. whence it rises gradually to its highest point near the SW. corner Sec. 8, T. 21 S., R. 21 E. From this high point it descends very gradually northeastward to a point near the east center of Sec. 5 whence it continues diagonally down the regional dip so that the present northeast end of the string is at least 25 feet below the high point. Further extension to the north or northeast will increase this closure to at least 35 feet.

Stated briefly, the string trends eastward almost directly up the regional dip for 8 miles, in which distance it rises 120 feet; it turns northeastward trending along the strike for about 2 miles, and thence continues northeastward diagonally down the regional dip (which here is northwest) so that a closure of at least 25 feet is already proved. This closure will be increased to at least 35 feet by any possible extension to the north or northeast.

What at first appeared to be a long channel sand body filled with oil without regard to structural conditions, has proved to be like the Colony gas pool described in the earlier paper[1] in that the sand body, on account of being closed by shale at the sides and on account of its course with respect to the regional dip, forms a closed anticlinal trap which is not related in any way to local structure.

With respect to the relation of oil production to structure, it is probably significant that the most productive part of the string has been the highest part of the trap in sections 18, 8, and 5 of T. 21 S., R. 21 E. In this area several wells had an initial flow of more than 200 barrels per day. One well in the SW. ¼ Sec. 8 is reported to have flowed 2,900 barrels of oil in the first 10 days. The point where the string crosses the minor structural high in E. ½ Sec. 15, T. 21 S., R. 20 E. has also been more productive than parts of the string on either side.

GARNETT STRING

Since the publication of the earlier paper the Garnett string has been extended westward 2 miles to the west side of Sec. 2, T. 21 S., R. 19 E. The sand body has been shown to extend for at least 2 miles farther west, but it is barren. Two wells, respectively 1 and 2 miles west of production, have struck the channel with its full 40

[1] *Loc. cit.*

feet of clean, porous sand which, however, carried only a stain and a slight showing of oil. This condition is similar to that at the west end of the Bush City string.

The reason for the lack of oil saturation is unknown, as the sand apparently carried no water. Two possible explanations may be mentioned, both of them requiring a lowering of the water level in the geological basin to the west. The first is structural. At the west side of Sec. 2 the string crosses a minor structural high trending north-south. East of that the string is "ponded" and its sand is saturated with oil. On the high, the sand carries so much gas that the oil yield is relatively small. West of the high the sand dips westward at somewhat more than the average regional rate. It is conceivable that oil may once have filled this part of the sand body and may have drained westward on withdrawal of the supporting water. The second explanation, which the writer is inclined to favor, is that the present western limit of production marks the approximate water level in the sand at the time the oil was accumulated and that the water has since withdrawn deeper into the basin, leaving the sand dry.

GOODRICH-PARKER STRING

At the west end of the Goodrich-Parker string in Secs. 24 and 25, T. 20 S., R. 21 E., and Sec. 30, T. 20 S., R. 22 E., a condition similar to that at the west end of the Bush City and Garnett strings has been found. The sand is present with thickness and porosity great enough to yield commercial wells, but the oil saturation is very poor—scarcely more than a stain and a mere showing.

A similar condition of poor saturation is found in the W. ½ Sec. 26, T. 20 S., R. 21 E., in line between the west end of the Goodrich-Parker string and the east end of the Bush City string as now known.

ANDERSON AND LINN COUNTY SHOESTRING POOLS POSSIBLY PARTS OF A SINGLE SYSTEM

The map, Figure 1, shows five shoestring pools, all at the same horizon, in their areal relation to each other. Their pattern at once suggests the broad outlines of a drainage system of which only fragments have been discovered. The pattern might be either that of a stream drainage system with branches joining toward the west, or

that of a delta distributary system branching out toward the east. That all of the strings, except possibly the Garnett string, are parts of a related system would seem scarcely to admit of doubt.

The Welda-Colony group of pools was discovered in the course of the drilling of the Colony-Welda gas string which lies at greater depth. The group appears to be partly fragments of shoestring channels not yet traced out, and partly pools in sand bodies of the bar type. Sand bodies of the latter type suggest open water deposition in that locality contemporaneous with the channel-filling farther north and east. This relation favors the theory that the shoestring channels are parts of a stream system draining westward rather than of a delta system branching eastward.

Origin of channels.—It is too early to determine definitely the nature and origin of this channel system, but a formulation of such possibilities as have suggested themselves, together with a statement of such facts as have a bearing on each, may be useful in guiding the search for additional significant facts.

Of the possible ways in which such a channel system might have been formed, the following three appear most likely: (1) A system of tidal channels in an extensive lagoon; (2) a delta distributary system; (3) a consequent drainage system resulting from a slight uplift and trenching of the Cherokee sea bottom, followed by silting up of the channels.

A brief discussion of the bearing of known facts on each of these hypotheses follows:

1. *Tidal channels.*—Examination of Coast Survey charts and airplane photographs of tidal channels shows that they differ from the Anderson and Linn County shoestring channels in being wide at the mouth, narrowing sharply, and meandering much more. Long, broadly swinging channels keeping a nearly uniform width for their whole length, such as are characteristic of the shoestrings, were not found among the tidal channels examined. In fact, the type pattern of the tidal channels is entirely different, Figure 3.

2. *Delta distributary channels.*—In pattern, the Anderson and Linn County shoestrings closely resemble delta distributaries. Dimensions, possible branching, depth of channel, nature of channel filling, and pattern of stream curves all resemble those of delta dis-

tributaries. Features of the shoestring channels which do not seem to favor the delta distributary explanation are: (*a*) The pattern of the shoestring channels appears to indicate branching to the eastward, which would require a stream flowing from the west into a water body to the east, whereas the center of the Cherokee basin is supposed to have been to the west of this area. (*b*) The blue shale of the upper part of the Cherokee in which the channels are cut is

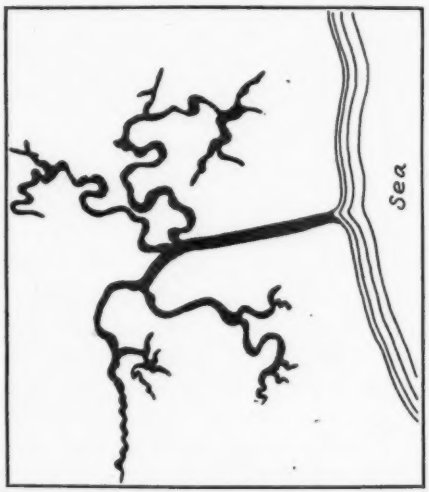

FIG. 3.—A typical system of tidal channels in a lagoon. Note the dissimilarity in pattern between these and the east-Kansas shoestring channels. Traced from an airplane photograph. See Willis T. Lee, "The Face of the Earth as Seen From the Air," *Amer. Geog. Soc., Special Publication No. 4*, p. 42.

an evenly bedded, non-sandy marine shale containing brachiopods. It is not the type of material which would be expected in a delta.

One feature of the shoestring channels which might be interpreted as favoring the delta distributary hypothesis is that where the white shale is found at the edge of the channel, outside of the deeper sand-filled part, this shale is commonly sandy and occurs slightly higher in the section than it does over the center of the channel. Its character and position are suggestive of the natural levee which borders all delta distributaries. Such a levee might, however, be

developed in the later stages of the silting up of a consequent drainage channel.

3. *Consequent drainage channels.*—The pattern of the shoestring channel system, so far as now revealed, accords with its interpretation as a system of consequent drainage channels resulting from a slight uplift of the Cherokee sea bottom. The supposed joining of the various branches toward the west, which would indicate drainage in that direction, accords with present theories that the axis of the Cherokee basin lay to the west.

The relation of the channel deposits to the underlying blue shale of the Cherokee formation accords much better with this hypothesis than with that of delta distributaries.

In so far as it is significant, the presence of the non-channel sand bodies of the Welda-Colony group of pools west of the principal shoestring channels now known indicates drainage westward and favors the consequent drainage hypothesis.

Of the three types of channel discussed present evidence seems to favor the consequent drainage type, but it must be emphasized that not enough data are at hand to permit definite conclusions. In the matter of the branching of the channels, particularly, we do not yet have the definite information desired. A number of features suggest that the channels branch more than present developments indicate. There is also a suggestion of a braided pattern of the channels in places and of their interconnection with each other in a more or less complex fashion. Proof of this must wait on further drilling. In the nature of the case it will probably come only accidentally, for operators are loath to drill outside the indicated trends of the pools, and suggestions of possible branching are not likely to be followed up if they lead outside the proven trends.

PROBLEM OF OIL ACCUMULATION

The existence of a system of narrow sand-filled channels spread over considerable parts of two counties has been demonstrated. Throughout the greater part of their known extent these channel sands are more or less thoroughly saturated with oil. Even in parts where oil is present only as a faint showing, no water has been encountered. How did the oil find its way into these narrow sand

bodies? What controls its distribution? What became of the water that must at one time have been associated with the oil? Why is a low degree of oil saturation so common? These are some of the problems raised by the shoestring pools.

Important light on some of these problems has been shed by recent developments. Most significant of these is probably the demonstration that the Bush City string is so related to the regional dip of the inclosing rocks that its eastern part forms a closed trap ideally suited to the accumulation and retention of oil and gas. This is the second shoestring pool in Anderson County which has been shown to form a closed trap on account of the relation of its trend to the regional dip. The first to be noted was the Colony gas string described in the earlier paper.

The finding of these two clear instances of oil and gas-filled traps caused by the broader relations of the sand bodies to the regional structure leads one to suspect that other shoestring pools may owe their oil and gas accumulations to a similar cause which would be obvious if the courses of the sand bodies in relation to the regional structure were known for their entire extent. It is suggested that even the long shoestring oil pools of Greenwood County, Kansas, may ultimately be found to have had their oil accumulation controlled by similar relations.

In the case of the Colony-Welda gas pool, the sand, which southwest of Colony carries water, extends diagonally up the regional dip out of the water; turns north along the strike for several miles, filled with gas all the way; and finally turns northwestward down the regional dip and again runs into water.

A somewhat similar condition with respect to water levels may have been present in both the Bush City and the Garnett sand bodies, which are known to extend westward beyond the present limits of oil saturation. Although no water is now present in these sands, it is believed that it may have been present when the oil was accumulated. Likewise, at the west end of the Goodrich string, the area where the sand is present but carries no commercial accumulation of oil may have been filled with water when the oil pools were originally formed. This area is distinctly synclinal and should have carried water if any were present in the sand at that time.

POSSIBLE EXPANSION OF THE OIL POOLS FOLLOWING LOSS OF WATER

At an earlier stage in the physiographic history of the region, when the oil sands were buried deeper than now, water was doubtless present in the sands at this horizon where they were not filled with oil or gas. It is likely that the oil pools in the channel sand bodies, though they contained all of the oil which they held before recent drilling, occupied a much smaller area than now and that the sands were fully saturated.

It is believed that on elevation of the region and erosion of its rock cover, accompanied by disappearance of the water by withdrawal into deeper parts of the basin or by evaporation into escaping gas, the pressure on the oil in the pools would have been decreased, the dissolved gas would have expanded, and the oil would have spread through parts of the sand previously occupied by water. In this way the area of the oil pools would have been increased at the same time that the degree of saturation of the sands would have been lessened and might locally have become very small. Sand lenses without outlet in the direction of spreading would have entrapped pockets of oil which would later prove much more fully saturated than surrounding sands—a condition now commonly found. Such is the explanation proposed for the present wide distribution of oil in the shoestring sands and the general low degree of saturation of the sands.

The source of the shoestring oil and its mode of accumulation in long, narrow sand bodies having relatively very small gathering area are among the many interesting problems which await solution.

April 5, 1926

THE FORAMINIFERA OF THE VELASCO SHALE OF THE TAMPICO EMBAYMENT

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ABSTRACT

This paper describes and illustrates the foraminiferal fauna of the Velasco shale which occurs above the Papagallos in the Tampico Embayment region. The species are very numerous and show very interesting relationships with a fauna of similar age in Europe.

The series gives considerable data in regard to the conditions of deposition and depth of water that probably accompanied the formation of this thick series of rather uniform shale. In some parts of the formation Foraminifera are very abundant, and the number of species is large.

The series of the Velasco shale as developed in the Tampico Embayment region probably represents the highest member of the Upper Cretaceous. It may be nearly a thousand feet thick, and is remarkably uniform as seen in the field and in well samples. This paper gives but a relatively small portion of the foraminiferal fauna. This fauna as a whole is very rich, but the shale is often hard and there is considerable difficulty in obtaining sufficient well-preserved specimens for descriptive work. In other parts of the formation it is possible to obtain very excellent suites of specimens. Owing to the chaotic condition in which the nomenclature of the Rotaliidae is at present, few of the very many species of this group are noted here.

As a whole the fauna represents offshore conditions. The shale is for the most part very fine grained, and there is a great preponderance of *Globigerina* throughout with some parts of the formation worthy of being described as a fossil *Globigerina*-ooze. The occurrence of many members of the Lagenidae also indicates fairly deep water. The correlation indicated by the fauna is with that of the Upper Cretaceous Navarro of Texas, although the Tampico Embayment during Velasco times must have been shut off from the north. The underlying Mendez shale may be very definitely correlated with the Taylor marl of Texas, and there are numerous species common to the two regions.

The Velasco, however, seems to be a deeper-water phase, and the absence of macroscopic fossils is very striking. Another of the unusual features is the almost complete absence of the Miliolidae, almost the only species, outside the genus *Cornuspira*, being one related to deeper-water forms of *Massilina* such as are found in the Tertiary and in Recent oceans at considerable depths.

The relationships of the Velasco fauna to that of the European Upper Cretaceous are very marked. Numerous species are apparently identical in the two areas, and show the close relationship of the Tampico Embayment in Velasco times to that of the Upper Cretaceous of England, France, and Central Europe.

Representative species of many of the genera except the Rotaliidae are here figured, and descriptions given of those that are not previously described. These include most of the more common species. All specimens, unless localities are given, are from the mass of Velasco shale as developed in the eastern part of the Hacienda El Limon, State of San Luis Potosi, Mexico.

Acknowledgment is due to Messrs. Earl Oliver, Chester A. Westfall, and to Dr. W. A. J. M. Van der Gracht for permission to publish the descriptions of the Mexican material, and to Mr. Earl A. Trager, whose careful supervision of the collection and preparation has made available abundant material for study. A description of the species follows:

Family Astrorhizidae

Genus *Ammodiscus* Reuss, 1861

Ammodiscus pleurostomarioides Chapman

Plate 15, Figures 3*a–c*

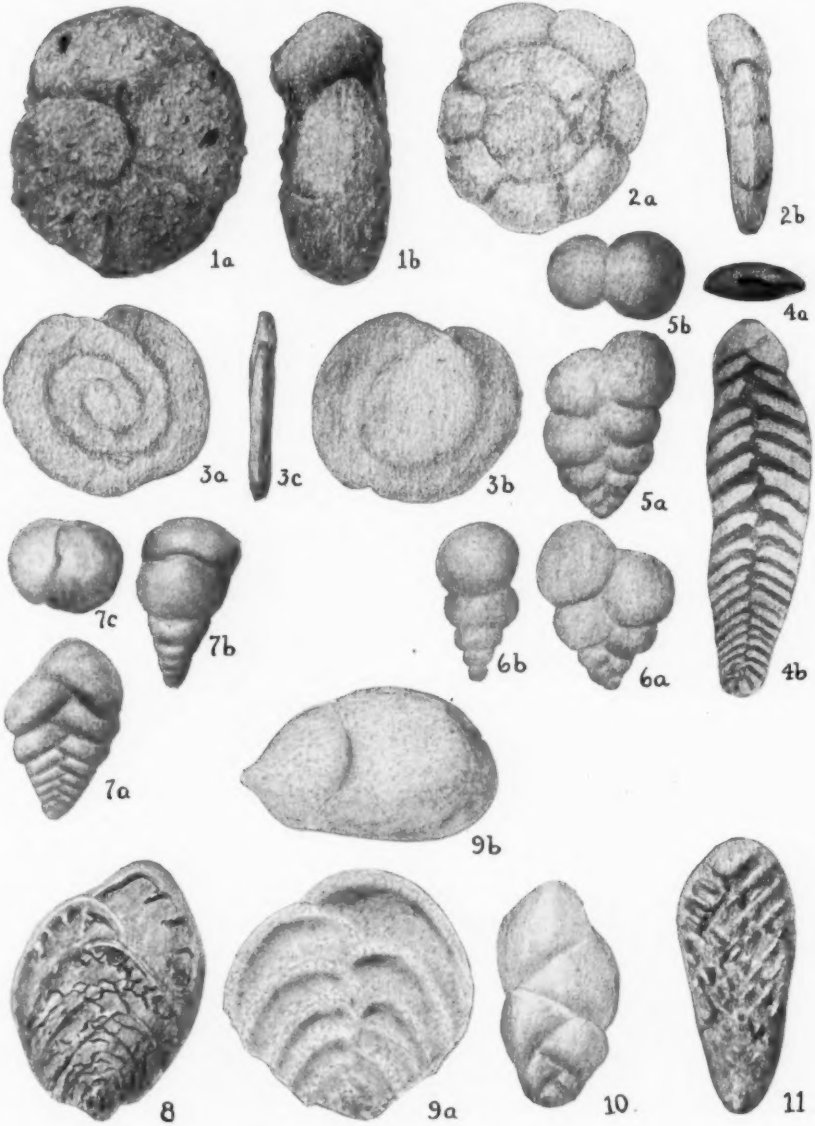
Ammodiscus pleurostomarioides Chapman, *Quart. Jour. Geol. Soc.* Vol. 50 (1894), p. 697, Pl. 34, Figs. 3*a*, *b*.

Test close-coiled, compressed on one side to a flat or even slightly concave surface, the other side convex, the tubular chamber semicircular in transverse section, the last coil being flattened and irregular, appearing as though it had been attached during growth.

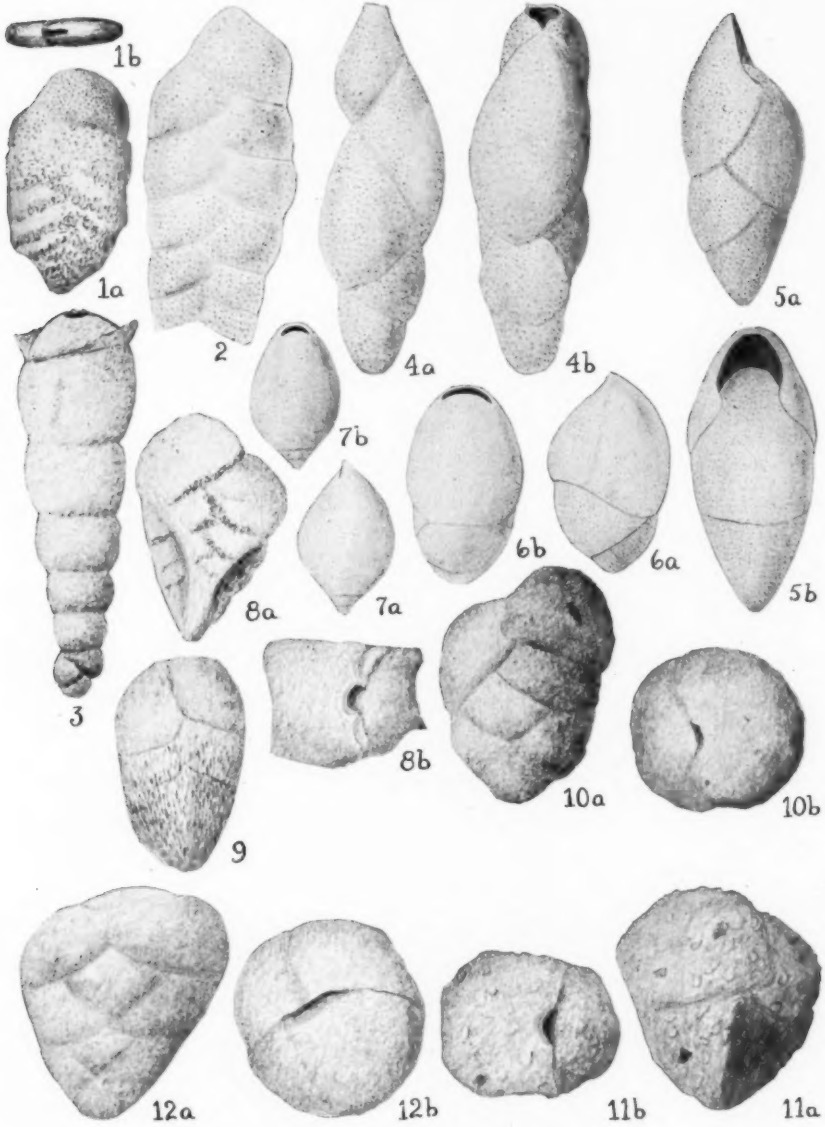
Diameter, 0.50 millimeter; thickness, 0.10 millimeter.

Figured specimen (Cushman Coll., No. 5132).

Chapman describes this species from the Cretaceous (Bargate beds) of Surrey, England. There are a few specimens in the Velasco shale, which, while they are not so convex as that shown in Chapman's figure, nevertheless do have a decidedly convex dorsal side in some specimens.



FORAMINIFERA OF THE VELASCO SHALE



FORAMINIFERA OF THE VELASCO SHALE

Family Lituolidae

Genus *Trochamminoides* Cushman, 1910

Trochamminoides velascoensis Cushman, n. sp.

Plate 15, Figures 2*a*, *b*

Test compressed, close-coiled, slightly inequilateral; chambers about eight in the last-formed coil, slightly more overlapping on the ventral than on the dorsal side, slightly depressed; wall slightly arenaceous but rather smoothly finished.

Diameter, 0.50 millimeter; thickness, 0.12 millimeter.

Holotype (Cushman Coll., No. 5133).

This species is related to *Trochamminoides proteus* (Karrer), but is more compressed, and is not bilaterally symmetrical, the chambers being much broader on the ventral side.

Genus *Haplophragmoides* Cushman, 1910

Haplophragmoides eggeri Cushman, n. sp.

Plate 15, Figures 1*a*, *b*

Haplophragmium fontinense Egger (not Terquem), *Ber. nat. Ver. Regensburg.* Vol. 12, 1907–9 (1910), p. 10, Pl. 3, Figs. 16–18.

Test close-coiled, compressed, of numerous chambers in about three coils, six or more chambers in the last-formed coil; sutures indistinct except between the last few chambers; wall rather coarsely arenaceous but the surface only slightly roughened; apertural face generally triangular, widest toward the base.

Diameter, 0.80 millimeter; thickness, 0.40 millimeter.

Holotype (Cushman Coll., No. 5134).

This is apparently identical with a form figured by Egger from the Upper Cretaceous of Regensburg, and referred by him to the Jurassic species described by Terquem as *Haplophragmium fontinense*, which is a very different species.

Genus *Nodosinella* Brady, 1876

Nodosinella velascoensis Cushman, n. sp.

Plate 20, Figures 9*a*, *b*

Test elongate, slender, chambers uniserial, distinct, slightly inflated, compressed, each chamber overlapping the previous one unequally, so that in side view the sutures are oblique; wall finely arenaceous but smoothly finished; aperture circular, terminal, facing toward the more overlapping side of the test.

Length, 0.80 millimeter; breadth, 0.25 millimeter.

Holotype (Cushman Coll., No. 5208).

This species is most closely allied to certain of those referred to this genus by Brady from the Carboniferous. It is a very peculiar form, but can be recognized even in single chambers. Complete forms are very rare and seldom found.

Family Textulariidae

Genus *Spiroplecta* Ehrenberg, 1844

Spiroplecta annectens (Parker and Jones)

Plate 15, Figures 4*a*, *b*

Textularia annectens Parker and Jones, *Ann. Mag. Nat. Hist.*, Ser. 3, Vol. 11 (1863), p. 92, Fig. 1.

Parker and Jones originally described this species as a *Textularia* from the Cretaceous (Gault) of England. It has been recorded numerous times as *Spiroplecta annectens* from the Cretaceous of Europe. It is an elongate form, somewhat variable in character, the widest of those in the Velasco shale often very closely approaching *Spiroplecta clotho* Grzybowsky described from the Cretaceous of Galicia.

Length, 0.80 millimeter; breadth, 0.18 millimeter; thickness, 0.08 millimeter. Figured specimen (Cushman Coll., No. 5135).

Genus *Textularia* Defrance, 1824

Textularia pupa Reuss

Plate 15, Figures 5*a*, *b*; 6*a*, *b*

Textularia pupa Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 40 (1860), p. 232, Pl. 13, Figs. 4, 5.

There are in the Velasco abundant specimens of a small *Textularia*, with a few globular chambers similar to the ones figured on Plate 15, and which may be referred to Reuss's species.

Length, 0.40 millimeter; breadth, 0.30 millimeter; thickness, 0.18 millimeter.

Figured specimens (Cushman Coll., No. 5136).

Textularia subglabra Cushman, n. sp.

Plate 15, Figures 7*a–c*

Test small, chambers numerous, low and broad, oblique, the whole test rhomboid in its side view, tapering from the initial end to the greatest width at the last two chambers, thickness also increasing progressively from the initial end, the last-formed chambers making the greatest thickness, nearly as long as broad in end view; chambers distinct, inflated, especially the later ones which are cut under on the lower side; sutures distinct, those between the later chambers very deep; wall smooth; aperture an elongate, narrow, slightly curved slit at the base of the last-formed chamber.

Length, 0.36 millimeter; breadth, 0.23 millimeter; thickness, 0.19 millimeter.

Holotype (Cushman Coll., No. 5137).

Textularia velascoensis Cushman

Plate 15, Figure 8

Textularia velascoensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 18, Pl. 3, Figs. 1*a–c*.

Test, in front view, oval, the initial end pointed, remainder of the test rather broadly oval, widest near the middle, in end view elliptical with the ends somewhat truncate; chambers comparatively few in number, fairly distinct except in the earlier portion; sutures distinct and limbate, raised; surface ornamented by the limbate sutures between which are raised projections extending back from the sutures themselves onto the lateral surfaces of the chambers with other irregular, raised areas, the sides of the test less ornamented, but in some specimens with a continuation of the same irregular, raised surface ornamentation; aperture elongate, low.

Length, up to 0.75 millimeter; breadth, 0.55 millimeter; thickness, 0.35 millimeter.

Holotype (Cushman Coll., No. 4343).

This is a very distinct species in the ornamentation, as has already been noted. It is an unusual one for this genus in all the specimens seen; while the pattern of the ornamentation is somewhat variable, nevertheless the main features of it remain fairly constant.

Textularia excolata Cushman, n. sp.
Plate 15, Figures 9*a*, *b*

Test fairly large, as broad as long, the sides much flattened or somewhat convex, periphery, of the early portion at least, acute; chambers few, the sides somewhat concave; sutures distinct and apparently raised, due to the thickening of the peripheral edge of the chambers, the surface below being somewhat concave; wall coarsely arenaceous but rather smoothly finished.

Length, 0.50 millimeter; breadth, 0.50 millimeter; thickness, 0.30 millimeter.

Holotype (Cushman Coll., No. 5138).

This is a very distinct species in the Velasco shales, but is never found in any considerable numbers.

Genus *Bigenerina* d'Orbigny, 1826
Bigenerina velascoensis Cushman, n. sp.
Plate 16, Figure 3

Test much elongate, tapering, greatest width formed by the last chamber, the first few chambers biserial, later ones uniserial, circular in transverse section; sutures distinct and depressed; wall arenaceous but smoothly finished; aperture circular, terminal.

Length, 0.85 millimeter; breadth, 0.25 millimeter.

Holotype (Cushman Coll., No. 5143).

This species is unusual in the very few chambers which keep to the biserial condition. It is rare so far as seen.

Genus *Bolivina* d'Orbigny, 1839

Bolivina decorata Jones

Plate 15, Figure 11

Bolivina decorata Jones, in Wright, *Proc. Belfast Nat. Field Club* 1884–85, *Appendix* 9 (1886), p. 330, Pl. 27, Figs. 7, 8; Wright, *Irish Naturalist* (1902), p. 179 (List); Heron-Allen and Earland, *Jour. Roy. Micr. Soc.* 1908, p. 336; 1910, p. 409, Pl. 7, Figs. 1, 2.

This species, originally described from the Cretaceous of Ireland, seems to be present in the Velasco shale. A figure is given (Plate 15, Figure 11), which gives the general character of the species, the chambers projecting back over the previously formed ones in finger-like processes, giving a very peculiar appearance to the test. The species is known from the Cretaceous of both Ireland and England.

Length, 0.65 millimeter; breadth, 0.20 millimeter.

Figured specimen (Cushman Coll., No. 5139).

Bolivina velascoensis Cushman, n. sp.

Plate 16, Figures 1*a*, *b*

Test very much compressed, the sides parallel for most of their length, the initial portion triangular, the chambers rapidly increasing in breadth, after which their breadth is kept constant during the rest of the growth; chambers fairly numerous, low, but increasing in height at the apertural end; sutures fairly distinct, the earlier ones covered with an irregular sculpture, the later ones depressed; wall of the earlier portion smooth except for the peculiar roughened ornamentation over the sutures, later chambers somewhat roughened throughout, the last-formed ones finely punctate; aperture elongate, elliptical.

Length, 0.05 millimeter; breadth, 0.25 millimeter; thickness, 0.05 millimeter.

Holotype (Cushman Coll., No. 5141).

Bolivina sp.?

Plate 15, Figure 10

There is a species here figured which apparently belongs to the genus *Bolivina*, which has a very few chambers and a smooth test. It is difficult to refer it to any described species.

Length, 0.50 millimeter; breadth, 0.25 millimeter.

Figured specimen (Cushman Coll. No. 5140).

Bolivina sp.?

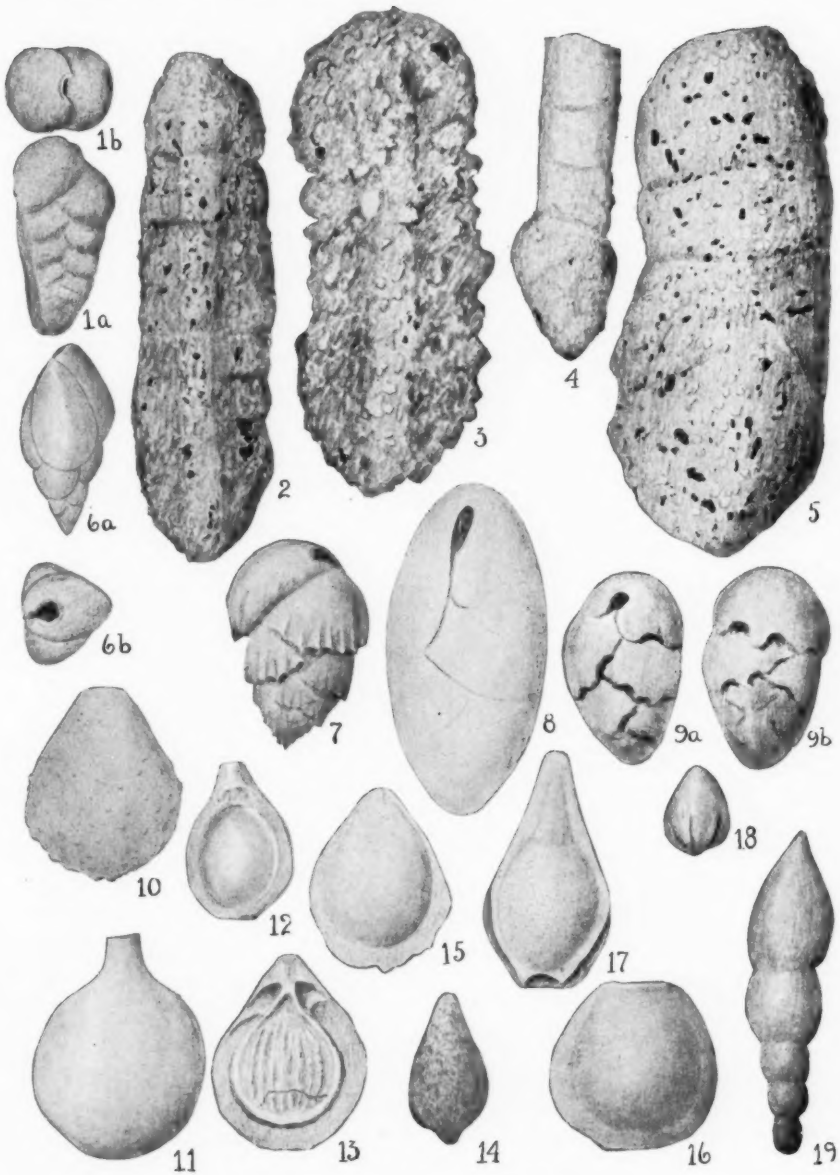
Plate 16, Figure 2

There is a species probably best referred to *Bolivina*, which is very thin, the chambers very distinct and nearly as high as broad, the periphery subcarinate, and wall smooth and polished. Complete specimens were difficult to obtain, and it has not seemed best to refer them to a definite specific name.

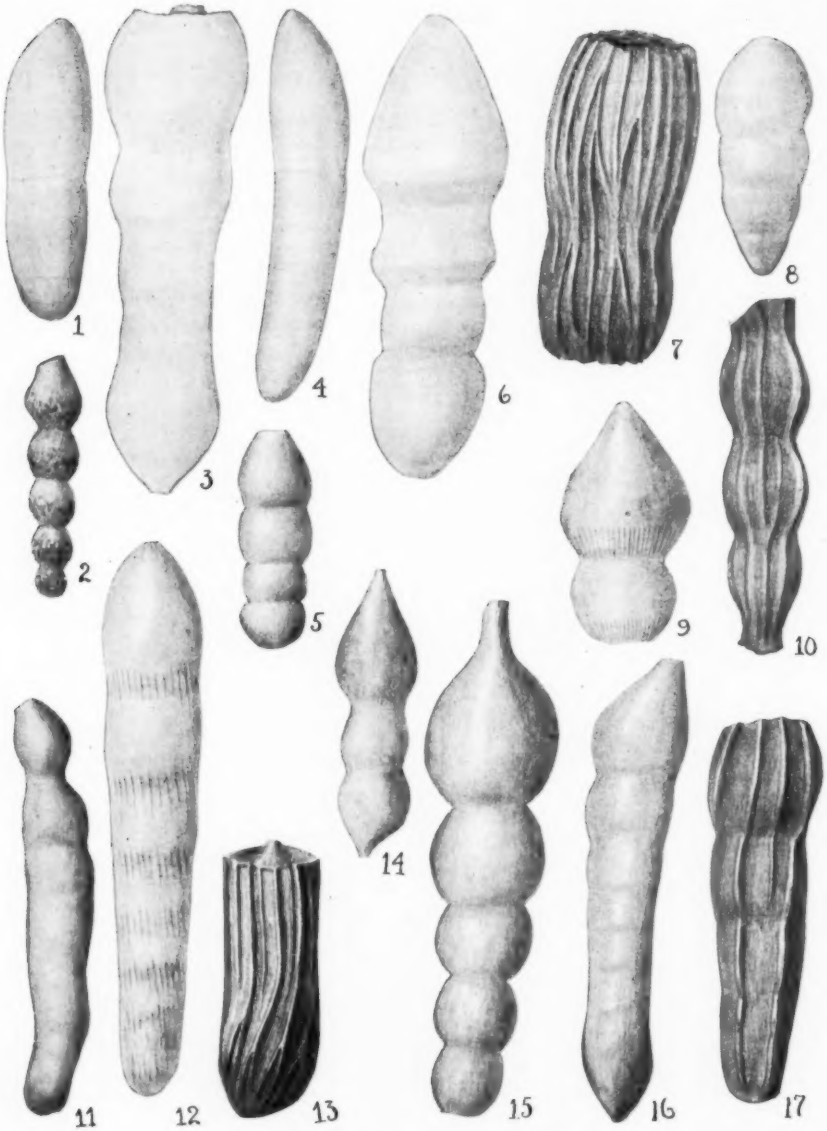
Breadth, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5142).

Genus *Verneuilina* d'Orbigny, 1840



FORAMINIFERA OF THE VELASCO SHALE



FORAMINIFERA OF THE VELASCO SHALE

Verneuilina sp.?
Plate 16, Figures 12*a*, *b*

There are numerous specimens in the Velasco shale which probably should be referred to this genus. One of the commonest of these is here figured. It is not unlike the specimen figured by Perner (1892, Plate 3, Figure 1) from the Cretaceous of Central Europe.

Diameter, 0.45 millimeter; length, 0.50 millimeter; thickness, 0.45 millimeter.

Figured specimen (Cushman Coll., No. 5152).

Genus *Gaudryina* d'Orbigny, 1839
Gaudryina laevigata Franke
Plate 17, Figures 1*a*, *b*

Gaudryina laevigata Franke, *Zeitschr. deutsch. geol. Ges.*, Vol. 66 (1914), p. 431, Pl. 27, Figs. 1, 2.

Test elongate, tapering, greatest breadth near the apertural end, early chambers triserial, forming a trihedral test, later chambers biserial and the test irregularly four-sided; chambers numerous, those of the early portion very low and broad, later ones higher; sutures distinct, very slightly depressed; wall arenaceous but very smoothly finished; aperture a long, low, somewhat arched opening at the base of the inner margin of the last-formed chamber.

Length, 0.45 millimeter; breadth, 0.20 millimeter; thickness, 0.17 millimeter.

Figured specimen (Cushman Coll., No. 5148).

This is very close to the form figured by Franke in the foregoing reference.

Gaudryina laevigata Franke, var. *pyramidata* Cushman, n. var.
Plate 16, Figures 8*a*, *b*

Test differing from the typical in the stouter form, the early portion more pyramidal than the type; the periphery, instead of rounded and convex, slightly concave.

Length, 0.55 millimeter; breadth, 0.30 millimeter; thickness, 0.25 millimeter.

Holotype (Cushman Coll., No. 5149).

Gaudryina velascoensis Cushman
Plate 16, Figure 9

Gaudryina velascoensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 20, Pl. 3, Figs. 7*a*, *b*.

Test elongate, about twice as long as broad, the early half generally triangular in transverse section, the later half quadrangular, the angles of the early portion very broadly rounded; chambers in the earlier triserial portion indistinct, in the later biserial portion somewhat more distinct; sutures indistinct except between the last three or four chambers, where they are slightly depressed; wall

in the early triserial portion with numerous fine, longitudinal striations, the later portion smooth and rather coarsely punctate; aperture very elongate, low.

Length, 0.70 millimeter; breadth, 0.40 millimeter.

Holotype (Cushman Coll., No. 4349).

This species is very distinct in the Velasco shale, characterized by its coarsely punctate wall, finely striate early portion with very rounded angles, and the later portion quadrangular.

Gaudryina retusa Cushman, n. sp.
Plate 16, Figures 10*a*, *b*

Test fairly large, stout, nearly circular in transverse section, composed of few chambers, early ones triserial, later ones biserial; chambers distinct, somewhat inflated; sutures distinct, in the later portion slightly depressed; wall arenaceous but rather smoothly finished; aperture comparatively small, low.

Length, 0.50 millimeter; breadth, 0.35 millimeter; thickness, 0.30 millimeter.

Holotype (Cushman Coll., No. 5150).

Gaudryina sp.?
Plate 16, Figures 11*a*, *b*

The form figured is somewhat related to *Gaudryina laevigata* Franke, and possibly represents the young of a much larger species; the early portion is sharply trihedral, and in the specimen but two biserial chambers are developed.

Length, 0.50 millimeter; breadth, 0.40 millimeter; thickness, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5151).

Genus *Clavulina* d'Orbigny, 1826
Clavulina trilatera Cushman, n. sp.
Plate 17, Figure 2

Test large, elongate, sides parallel for most of their length, slightly contracted at either end, entire test triangular in transverse section, the periphery rounded, the sides concave; chambers numerous, the early ones triserial, later ones, forming the larger part of the test, uniserial; sutures very slightly if at all depressed, somewhat indistinct; wall coarsely arenaceous but very smoothly finished; aperture terminal, circular, with a very slight neck.

Length, 1.15 millimeters; breadth, 0.35 millimeter; thickness, 0.35 millimeter.

Holotype (Cushman Coll., No. 5155).

This species somewhat reminds one of certain of the forms of the Upper Cretaceous, which are referred to *Tritaxia*. The main portion of the test, however, is uniserial, the early portion triserial, making it a true *Clavulina*.

Clavulina trilatera Cushman, n. sp., var. *aspera* Cushman, n. var.
Plate 17, Figure 3

Test differing from the typical in its much larger size, usually shorter, stouter form, and the very coarsely arenaceous wall, roughly finished.

Length, 1.10 millimeters; breadth, 0.45 millimeter; thickness, 0.45 millimeter.

Holotype (Cushman Coll., No. 5154).

This is apparently related to the preceeding species, but through the material seen it may be readily distinguished from the typical.

Clavulina clavata Cushman, n. sp.
Plate 17, Figure 4

Test of peculiar shape, the early triserial portion increasing rather rapidly in diameter, the periphery rounded but the transverse section triangular, followed abruptly by the uniserial portion, in which the chambers are circular in transverse section and the diameter is considerably less than the preceeding triserial portion; wall finely arenaceous and rather smoothly finished; sutures rather indistinct.

Length, 0.75 millimeter; breadth, 0.25 millimeter; thickness, 0.25 millimeter.

Holotype (Cushman Coll., No. 5156).

This species is a peculiar one in its general form and the abrupt contraction in the uniserial portion. It is very restricted in its vertical distribution in the Velasco, but rather widely distributed in that particular horizon.

Clavulina amorpha Cushman, n. sp.
Plate 17, Figure 5

Test large, stout, two or three times as long as broad, early portion triserial; chambers indistinct, roughly triangular in section, the later portion uniserial, circular in transverse section, composed of a few large inflated chambers nearly as broad as the early triserial portion, with no abrupt break between the two parts; sutures in the last-formed portion slightly depressed, distinct; wall coarsely arenaceous but with a large proportion of cement and smoothly finished; aperture large, circular, terminal.

Length, 1.20 millimeters; breadth, 0.50 millimeter; thickness, 0.50 millimeter.

Holotype (Cushman Coll., No. 5153).

This is a large species, the general form of which is not as distinct as in most other species of the genus; the early portion is a rounded, slightly triangular mass followed by a few large, inflated chambers.

Family Ellipsoidinidae

Genus *Pleurostomella* Reuss, 1860

Pleurostomella velascoensis Cushman, n. sp.

Plate 16, Figures 4*a*, *b*

Test elongate, composed of few chambers, biserial throughout, inflated, the periphery lobulate; sutures distinct, depressed except in the early portion; wall smooth, finely perforate; the aperture becoming nearly terminal, the inner border cut down to the previously formed chamber.

Length, 0.80 millimeter; breadth, 0.25 millimeter; thickness, 0.25 millimeter.

Holotype (Cushman Coll., No. 5144).

This species is an unusual one for this genus, which usually has the aperture open and at one side rather than terminal. This species somewhat resembles figures which Egger has referred to *Pleurostomella alternans* Schwager, but which are evidently not that species. His specimens were from the Upper Cretaceous of Bavaria.

Pleurostomella clavata Cushman, n. sp.

Plate 16, Figures 5*a*, *b*

Test somewhat fusiform, nearly circular in transverse section, greatest height toward the apertural end, periphery very slightly, if at all, lobulate, composed of a few chambers; the sutures distinct but not depressed; wall smooth, finely perforate; aperture at the base of the last-formed chamber very large, arched.

Length, 0.65 millimeter; breadth, 0.25 millimeter; thickness, 0.25 millimeter.

Holotype (Cushman Coll., No. 5145).

Genus *Ellipsopleurostomella* Silvestri, 1904

Ellipsopleurostomella curta Cushman, n. sp.

Plate 16, Figures 6*a*, *b*

Test short and stout, composed of a very few chambers, somewhat inflated; the sutures distinct but very slightly, if at all, depressed; wall smooth and finely perforate; aperture an elongate narrow curved slit, as is usual in the genus.

Length, 0.45 millimeter; breadth, 0.25 millimeter; thickness, 0.25 millimeter.

Holotype (Cushman Coll., No. 5146).

This species is a very short, stout one, but has the characteristic aperture of the genus.

Genus *Ellipsoglandulina* Silvestri

Ellipsoglandulina velascoensis Cushman, n. sp.

Plate 16, Figures 7*a*, *b*

Test small, fusiform, greatest width about the middle, thence tapering to the bluntly pointed ends; chambers few, much overlapping; sutures distinct;

wall smooth, finely perforate; aperture an elongate, narrow curved slit at one side, near the end of the last-formed chambers.

Length, 0.35 millimeter; breadth, 0.20 millimeter; thickness, 0.20 millimeter.

Holotype (Cushman Coll., No. 5147).

Genus Ellipsosiphogenerina Silvestri

Ellipsosiphogenerina sp.?

Plate 20, Figures 11, 12

There are a few specimens, such as figured in Plate 20, Figures 11, 12, which possibly may be referred to this genus proposed by Silvestri for specimens which have the characters of *Siphogenerina*, but with the *Ellipsoidina* aperture. The Velasco specimens have the early chambers biserial and the later ones uniserial, with the aperture terminal and ellipsoid.

Length, 0.85 millimeter; breadth, 0.25 millimeter.

Figured specimens (Cushman Coll., No. 5209).

Genus *Bulimina* d'Orbigny, 1826

Bulimina trihedra Cushman, n. sp.

Plate 17, Figures 6*a*, *b*

Test small, very distinctly trihedral, the angles rounded, sides nearly flat and slightly convex; chambers numerous, distinct, inflated, longer than broad; sutures distinct, depressed; wall very smooth, polished; aperture oval.

Length, 0.40 millimeter; breadth, 0.20 millimeter; thickness, 0.20 millimeter.

Holotype (Cushman Coll., No. 5160).

This is an unusual form of the test for this genus, the species being at once recognized by its very decidedly trihedral form. It is often abundant, but is very strictly limited in its vertical distribution.

Bulimina cf. *inflata* Seguenza

Plate 17, Figure 7

There are often abundant specimens in the Velasco shales, which strongly resemble *Bulimina inflata* Seguenza. There is a considerable difference in the ornamentation of the periphery of the chambers at different horizons in the Velasco, and it possibly may be that later work will show that more than one definite form is involved.

Length, 0.45 millimeter; breadth, 0.30 millimeter; thickness, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5159).

Bulimina cf. *ovata* d'Orbigny

Plate 17, Figure 8

There is a large species, found rather widely distributed in the Velasco shales, with a fusiform shape, the ends rounded; sutures rather indistinct;

aperture elongate oval; walls smoothly finished. It may be referred to the above species of d'Orbigny until more is known of its structure.

Length, 0.75 millimeter; breadth, 0.35 millimeter; thickness, 0.35 millimeter.

Figured specimen (Cushman Coll., No. 5158).

Bulimina incisa Cushman, n. sp.
Plate 17, Figures 9*a*, *b*

Test small, oval, circular in transverse section, greatest breadth toward the apertural end, initial end rounded; chambers comparatively few, distinct, especially the later ones; sutures distinct, depressed, the basal edge of each chamber with numerous re-entrants, which apparently are cut in along the suture lines; wall smooth; aperture broadly oval.

Length, 0.45 millimeter; breadth, 0.30 millimeter; thickness, 0.30 millimeter.

Holotype (Cushman Coll., No. 5157).

This species is peculiar in the sculpturing along the sutural lines, the basal edge of the chamber being sinuous, composed of deeply cut-in areas between which the edge of the chamber projects backward over the preceding one.

Family Lagenidae
Genus *Lagena* Walker and Boys, 1784
Lagena aspera Reuss
Plate 17, Figure 10

Lagena aspera Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 44, Part 1, 1861 (1862), p. 305, Pl. 1, Fig. 5.

There are specimens which occur rarely in the Velasco shales which have the general appearance of the figured specimen. The surface is ornamented by scattered papillae, especially the lower half. The specimens are not typical.

Length, 0.40 millimeter; breadth, 0.35 millimeter.

Figured specimen (Cushman Coll., No. 5161).

Lagena globosa (Montagu)
Plate 17, Figure 11

Serpula (*Lagena*) *laevis globosa* Walker and Boys, *Test. Min.* (1784), p. 3, Pl. 1, Fig. 8.

Vermiculum globosum Montagu, *Test. Brit.* (1803), p. 523.

There are specimens of a globular form, with a short cylindrical neck, which may be referred to *Lagena globosa*. They are not common.

Length, 0.45 millimeter; breadth, 0.35 millimeter; thickness, 0.35 millimeter.

Figured specimen (Cushman Coll., No. 5165).

Lagena orbignyana (Seguenza)
Plate 17, Figure 12

Fissurina orbignyana Seguenza, *Foram. mon. mioc. Messina* (1862), p. 66, Pl. 2, Figs. 25, 26.

Lagena orbignyana H. B. Brady, Rep. Voy. Challenger, *Zoölogy*, Vol. 9 (1884), p. 484, Pl. 59, Figs. 1, 18, 24–26.

This is one of the forms referred to this species by various authors. The central portion is smooth, while in the following variety there is a considerable amount of ornamentation developed.

Length, 0.35 millimeter; breadth, 0.25 millimeter.

Figured specimen (Cushman Coll., No. 5162).

Lagena orbignyana (Seguenza), var.
Plate 17, Figure 13

This variety differs from the typical form of the species in the broader wing-like periphery and the central portion, which is longitudinally costate.

Length, 0.40 millimeter; breadth, 0.30 millimeter.

Holotype (Cushman Coll., No. 5167).

Lagena sp.?
Plate 17, Figure 14

The peculiar form figured occurs rarely in the Velasco shale. It is fusiform in shape, with the initial end slightly produced, the surface roughened.

Length, 0.30 millimeter; breadth, 0.16 millimeter; thickness, 0.16 millimeter.

Figured specimen (Cushman Coll., No. 5169).

Lagena marginata d'Orbigny
Plate 17, Figures 15, 16

There are a number of specimens in the Velasco shales which have developed a peripheral wing. These evidently do not belong to one species, but they have occurred rarely and are usually not in a very good state of preservation, so that it is probably not well to place them too definitely until more material is available for study.

Figured specimens (Cushman Coll., Nos. 5163, 5164).

Lagena foveolata Reuss, var.
Plate 17, Figure 17

The specimen figured shows characters which are somewhat similar to this species, the sides toward the base having the peripheral carina split so that an open space is developed between the two parts. The surface is smooth and finely perforate.

Length, 0.50 millimeter; breadth, 0.25 millimeter.

Figured specimen (Cushman Coll., No. 5166).

Lagena quadricostulata Reuss
Plate 17, Figure 18

There is a small species of subglobular form, broadest toward the base, with four to six costae on the basal half. These may be referred provisionally to the above species. There were not enough specimens available for full description.

Length, 0.18 millimeter; breadth, 0.13 millimeter; thickness, 0.13 millimeter.

Figured specimen (Cushman Coll., No. 5168).

Genus *Nodosaria* Lamarck, 1812
Nodosaria (*Glandulina*) *cylindracea* Reuss
Plate 18, Figured 1

Nodosaria (*Glandulina*) *cylindracea* Reuss, *Verstein, Böhm. Kreide*, Vol. 1 (1845–46), p. 25, Pl. 13, Figs. 1, 2.

Specimens which may be referred to this species are rather widely distributed through the section represented by the Velasco shales. The species is recorded from the Cretaceous of Europe by numerous authors.

Length, 0.72 millimeter; breadth, 0.20 millimeter.

Figured specimen (Cushman Coll., No. 5180).

Nodosaria (*Glandulina*) *manifesta* (Reuss)
Plate 18, Figure 8

Nodosaria manifesta Reuss, *Haidinger's Nat.*, Vol. 4, Part 1 (1851), p. 22, Pl. 1, Fig. 4.

Reuss described from the Cretaceous of Lemberg a form which is very similar to that figured here, Plate 18, Figure 8. Such forms are fairly common, with a wide distribution in the Velasco shales.

Length, 0.50 millimeter; breadth, 0.20 millimeter.

Figured specimen (Cushman Coll., No. 5177).

Nodosaria tenuicollis Reuss
Plate 18, Figure 11

Nodosaria tenuicollis Reuss, *Zeitschr. deutsch. geol. Ges.*, Vol. 7 (1855), p. 267, Pl. 8, Fig. 11.

A peculiar form, which is rather rare in the Velasco shales, has in some ways a considerable resemblance to the species described by Reuss from the Cretaceous of Europe. It is rare.

Length, 1.20 millimeters; breadth, 0.22 millimeter.

Figured specimen (Cushman Coll., No. 5179).

Nodosaria fontannesi (Berthelin), var. *velascoensis* Cushman, n. var.
Plate 18, Figure 12

Test elongate, subcylindrical, very slightly tapering, greatest width developed by the last-formed chamber, consisting of numerous chambers increasing

in height as added, the last ones somewhat longer than broad, circular in transverse section; sutures only slightly depressed, ornamentation consisting of very fine longitudinal costae which in the early portion may be continuous, but over most of the test are restricted to the areas over the sutures.

Length, 1.45 millimeters; breadth, 0.30 millimeter.

Holotype (Cushman Coll., No. 5178).

This is a large and striking form and has a wide vertical range in the Velasco shales. The typical form of the species was described by Berthelin from the Cretaceous of France.

Nodosaria limbata d'Orbigny
Plate 18, Figure 14

Nodosaria limbata d'Orbigny, *Mém. Soc. Géol. France*, Ser. 1, Vol. 4 (1840), p. 12, Pl. 1, Fig. 1.

D'Orbigny described the species from the Cretaceous of France, and our species from this Upper Cretaceous, Velasco shale material seem to be very similar.

Length, 0.60 millimeter; breadth, 0.18 millimeter.

Figured specimen (Cushman Coll., No. 5181).

Nodosaria praegnans Reuss
Plate 18, Figure 15

Nodosaria praegnans Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 52, Part 1, 1865 (1866), p. 450, Pl. Fig. 4.

There are large specimens with subglobose chambers and deeply indented sutural areas, with the apertural end produced into a fairly long cylindrical neck, which are very close to this species described by Reuss from the Cretaceous of Europe.

Length, 1.10 millimeters; breadth, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5182).

Nodosaria megalopolitana (Reuss)
Plate 18, Figure 16

Dentalina megalopolitana Reuss, *Zeitsch. deutsch. geol. Ges.*, Vol. 7 (1855), p. 267, Pl. 8, Fig. 10.

The specimen figured is very close to this species described by Reuss from the Cretaceous of Europe.

Length, 1.35 millimeters; breadth, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5184).

Nodosaria prismatica Reuss.
Plate 18, Figure 17

Nodosaria prismatica Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 40 (1860), p. 180, Pl. 2, Fig. 2.

Specimens from the Cretaceous of various regions have been referred to this species which Reuss described from the Cretaceous of Europe. It is characterized by rather close-set chambers with the sutures only slightly depressed and the whole test ornamented with a very few distinct longitudinal costae.

Length, 0.80 millimeter; breadth, 0.23 millimeter.

Figured specimen (Cushman Coll., No. 5183).

Nodosaria expansa Reuss
Plate 18, Figure 4

Dentalina expansa Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 40 (1860), p. 188, Pl. 3, Fig. 4.

The figured specimen is close to figures referred to this species by Chapman from the Cretaceous (Gault) of England.

Length, 0.80 millimeter; breadth, 0.15 millimeter.

Figured specimen (Cushman Coll., No. 5175).

Nodosaria limonensis Cushman
Plate 18, Figures 7?, 13.

Nodosaria limonensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1. Part 1 (1925), p. 21, Pl. 3, Figs. 4*a*, *b*.

Test elongate, subconical, widest near the base, circular in transverse section; chambers indistinct from the surface; sutures indistinct; wall ornamented by a series of eight broad, prominent, longitudinal costae which, toward the base, become bifurcate; between these, above the early portion, are very thin, delicate, longitudinal costae alternating with the thick ones; aperture somewhat projecting, radiate.

Length of type specimen, which is evidently incomplete, 0.85 millimeter; breadth at base, 0.25 millimeter.

Holotype (Cushman Coll., No. 4346).

The type specimen which is figured, Plate 4, Figure 13, is incomplete. Plate 18, Figure 7, is a fragment consisting of two chambers, evidently from a large specimen which, on account of the peculiar bifurcating costae, resembles this species. It may be a later development or this resemblance may be purely a superficial one. No complete specimens of the species have been found.

Nodosaria ambigua Neugeboren
Plate 18, Figure 5

Nodosaria ambigua Neugeboren, *Denkschr. Akad. Wiss. Wien*, Vol. 12, Part 2 (1856), p. 71, Pl. 1, Figs. 13–16.

This represents a form which is not uncommon in the Velasco, which, in its few inflated chambers and the sides nearly parallel, is very close to the above reference.

Length, 0.70 millimeter; breadth, 0.22 millimeter.

Figured specimen (Cushman Coll., No. 5202).

Nodosaria sceptriformis Gümbel
Plate 18, Figure 10

Nodosaria sceptriformis Gümbel, *Abhandl. kön. bay. Akad. Wiss. München*, Cl. II, Vol. 10, 1868 (1870), p. 620, Pl. 1, Fig. 33.

The form figured resembles very closely those referred by Gümbel to this species. They are ornamented with a few longitudinal costae which are high and sharp and the chambers rather distinctly separated from one another. Such forms are usually broken on account of weakness developed at the constrictions, but are nevertheless rather common in Velasco shales.

Breadth, 0.20 millimeter.

Figured specimen (Cushman Coll., No. 5203).

Nodosaria cf. *adolphina* d'Orbigny
Plate 18, Figure 2

A few specimens of a somewhat slender form, with the posterior half of each chamber roughened or slightly spinose, have been found. Egger records this species from the Cretaceous, but they do not seem to be identical with the typical form of the species from the later Tertiary.

Length, 0.50 millimeter; breadth, 0.11 millimeter.

Figured specimen (Cushman Coll., No. 5174).

Nodosaria soluta (Reuss)
Plate 17, Figure 19; Plate 18, Figure 9

Dentalina soluta Reuss, *Zeitschr. deutsch. geol. Ges.*, Vol. 3 (1851), p. 60, Pl. 3, Fig. 4.

Nodosaria soluta Reuss, *Denkschr. Akad. Wiss. Wien*, Vol. 25 (1865), p. 131, Pl. 2, Figs. 4–8.

Numerous specimens of the form here figured are referred to *Nodosaria soluta* (Reuss). They are fairly common in some parts of the Velasco shale. Most of the specimens referred to this species from recent oceans have an ornamentation such as that seen in Plate 18, Figure 9. It does not occur, however, in all specimens, and it may be that better material will show that more than one species is included.

Figured specimens (Cushman Coll., Nos. 5170, 5171).

Nodosaria sp.?
Plate 18, Figures 3, 6

There are incomplete specimens of a large Nodosarian form figured here, Plate 18, Figure 3. No complete ones were found, and it is difficult to refer them to any described species. The same is true of Plate 18, Figure 6, which seems at first glance to be an abnormal specimen. This later form, however, has a rather definite vertical distribution, and its main peculiarity consists of the collar-like enlargement at the base of each chamber.

Length, 1.15 millimeters; breadth, 0.35 millimeter.
Figured specimens (Cushman Coll., Nos. 5172, 5173).

Genus *Frondicularia* Defrance, 1824

Frondicularia sp?.
Plate 20, Figure 2

There are frequently found, in the Velasco material, fragments of the initial portion of a *Frondicularia* with a few longitudinal ribs, the sutures small, limbate, but not otherwise conspicuous. Without more complete specimens it does not seem best to refer these to a definite specific name.

Breadth, 0.40 millimeter.
Figured specimen (Cushman Coll., No. 5205).

Frondicularia cf. *interpunctata* (Von der Marck)
Plate 20, Figure 3

Frondicularia interpunctata Von der Marck, *Verh. nat. Ver. preuss. Rheinl.*, Vol. 15 (1858), p. 53, Pl. 1, Fig. 5.

There is a species—the most common one of the genus—in the Velasco which has a flattened test with prominent raised sutures, the area between variously ornamented. In the figured specimen this ornamentation takes on the character of a network of raised lines. Occasionally these are not nearly so prominent, and the specimens then become more like the typical form of this species.

Length, 0.55 millimeter; breadth, 0.35 millimeter.
Figured specimen (Cushman Coll., No. 5206).

Frondicularia sp.?
Plate 20, Figure 4

The form figured is a very peculiar one, probably best referred to this genus. The aperture has a definite neck, and thus differs from most of the species of this genus, which usually have a conical apertural end with a radiate aperture.

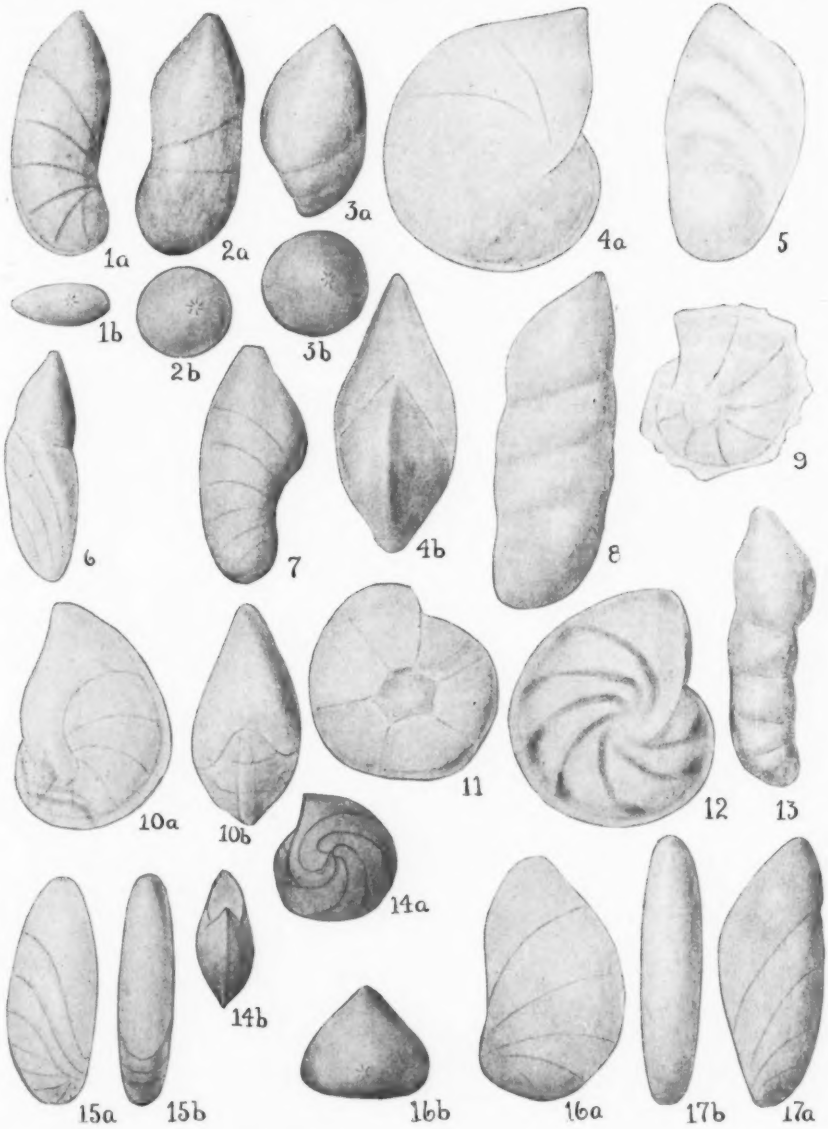
Length, 0.90 millimeter; breadth, 0.35 millimeter.
Figured specimen (Cushman Coll., No. 5207).

Genus *Cristellaria* Lamarck, 1812
Cristellaria grata Reuss
Plate 19, Figures 1*a*, *b*

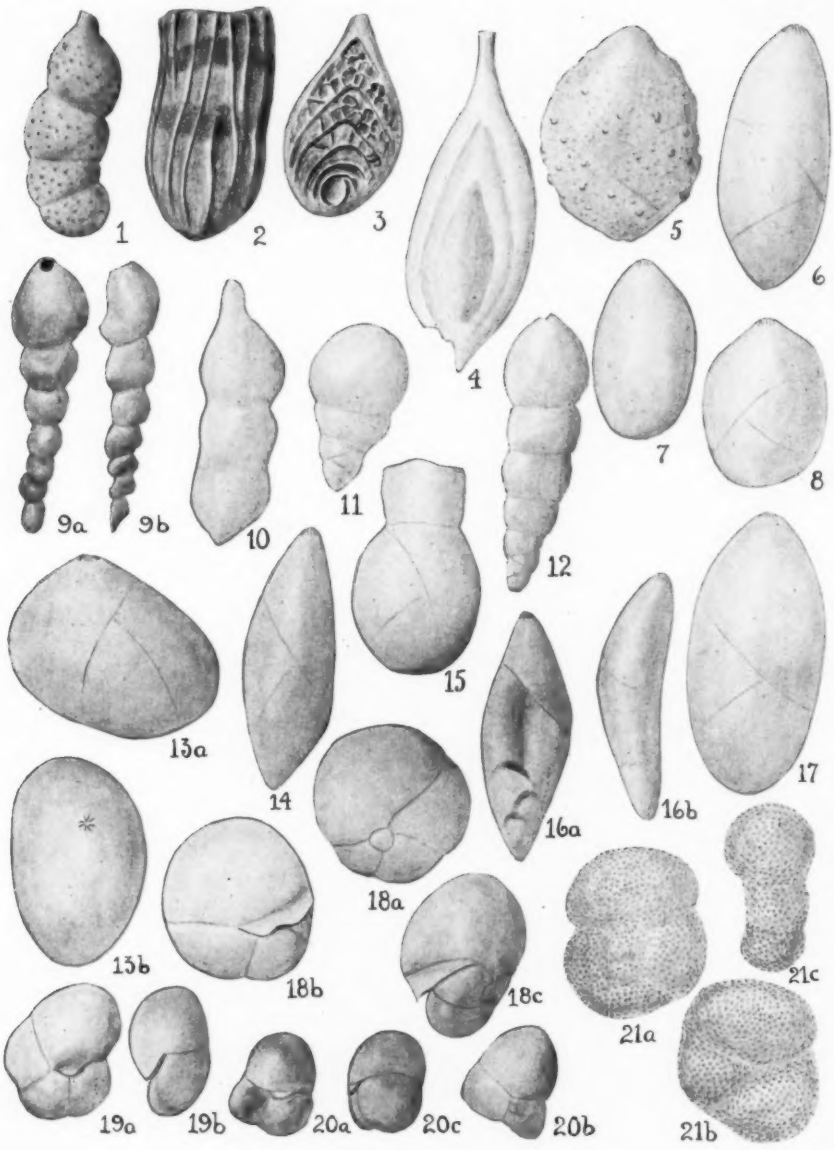
Cristellaria grata Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 46, Part 1, 1862 (1863), p. 70, Pl. 7, Fig. 14*a*, *b*.

There are occasional specimens such as that figured here, Plate 19, Figure 1, which may be referred to this species described by Reuss.

Length, 0.65 millimeter; breadth, 0.30 millimeter.
Figured specimen (Cushman Coll., No. 5200).



FORAMINIFERA OF THE VELASCO SHALE



FORAMINIFERA OF THE VELASCO SHALE

Cristellaria rotulata (Lamarck)
Plate 19, Figures 4*a*, *b*

Lenticulites rotulata Lamarck, *Ann. Mus.*, Vol. 5 (1804), p. 188; Vol. 8, (1806), Pl. 62, Fig. 11.

Cristellaria rotulata d'Orbigny, *Mém. Soc. Géol. France*, Ser. 1, Vol. 4 (1840), p. 26, Pl. 2, Figs. 15–18.

D'Orbigny records this species from the Cretaceous of the Paris Basin. Lamarck's specimens were from the Eocene of the same general region. The name has been applied to the smooth *Cristellaria* with an acute periphery, from almost every region and at least Cretaceous and Tertiary formations. There are many distinct forms or species passing under this name, which need much patient research to place finally in their true position.

Length, 0.75 millimeter; breadth, 0.65 millimeter.

Figured specimen (Cushman Coll., No. 5187).

Cristellaria trunculata Berthelin
Plate 19, Figures 2*a*, *b*

Cristellaria trunculata Berthelin, *Mém. Soc. Géol. France*, Ser. 3, Vol. 1 (1880), p. 53, Pl. 3 (26), Figs. 26, 27.

This short stout form, nearly circular in transverse section, is apparently identical with this species of Berthelin described from the Upper Cretaceous of France.

Length, 0.65 millimeter; breadth, 0.25 millimeter.

Figured specimen (Cushman Coll., No. 5185).

Cristellaria diadémata Berthelin
Plate 19, Figure 9

Cristellaria diadémata Berthelin, *Mém. Soc. Géol. France*, Ser. 3, Vol. 1 (1880), p. 51, Pl. 3 (26), Figs. 4, 5, 12, 13.

Numerous specimens occur in the Velasco shales which may be referred to this Cretaceous species. It was originally described by Berthelin from the Cretaceous (Gault) of France, and has since been recorded from European Cretaceous by other authors. It is characterized by a thin keel which is dentate, with distinct chambers and sutures, almost, but not quite, involute.

Length, 0.55 millimeter; breadth, 0.55 millimeter.

Figured specimen (Cushman Coll., No. 5189).

Cristellaria cf. *lepida* (Reuss)
Plate 19, Figures 10*a*, *b*

There are very rare specimens in the Velasco which have the peculiar form here figured, Plate 19, Figure 10, in which the last-formed chambers have a broad extension in the umbilical region. Similar specimens have been figured by Egger and Reuss from the Cretaceous of Europe.

Length, 0.65 millimeter; breadth, 0.45 millimeter.
Figured specimen (Cushman Coll., No. 5192).

Cristellaria cf. *gaultina* Berthelin
Plate 19, Figure 12

There are frequently found in the Velasco shales specimens similar to that figured here, but with the sutures less curved, the test smooth, and either with an acute periphery or slightly keeled. Such specimens are very close to *Cristellaria gaultina* described by Berthelin from the Cretaceous (Gault) of France, and recorded by other authors from the Cretaceous of different parts of Europe.

Length, 0.70 millimeter; breadth, 0.70 millimeter.
Figured specimen (Cushman Coll., No. 5194).

Cristellaria schloenbachi Reuss
Plate 19, Figure 13

Cristellaria schloenbachi Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 46, Part 1, 1862 (1863), p. 65, Pl. 6, Figs. 14, 15.

This species was originally described by Reuss from the Cretaceous of North Germany, and is recorded by other authors from the Cretaceous of Saxony, Bavaria, and the other parts of Germany, as well as from the Cretaceous of England. Recent material has been referred to this, but it is not always apparent that the two should be considered the same.

Our specimens from the Cretaceous of Mexico agree very closely with those figured by European authors from the Cretaceous.

Length, 0.90 millimeter; breadth, 0.25 millimeter.
Figured specimen (Cushman Coll., No. 5193).

Cristellaria crepidula (Fichtel and Moll)
Plate 19, Figures 15*a*, *b*

Nautilus crepidula Fichtel and Moll, *Test. Micr.* (1798), p. 107, Pl. 19, Figs. *g–i*.

Cristellaria crepidula d'Orbigny, in "Foraminiferes," *De la Sagra Hist. Phis. Pol. Nat., Cuba* (1839), p. 41, Pl. 8, Figs. 17, 18.

A great many forms from the Cretaceous to the Recent have been assigned to this species. The specimens figured here agree as closely with it as do many others. It is a smooth species with rounded periphery, the early portion somewhat closely coiled, later ones breaking away, forming an uncoiled test.

Length, 0.65 millimeter; breadth, 0.27 millimeter.
Figured specimen (Cushman Coll., No. 5196).

Cristellaria cf. *navicula* d'Orbigny
Plate 19, Figures 16*a*, *b*

There are specimens in the Velasco which have the same general form as that here figured, Plate 19, Figure 16, in which there are but a few chambers in the test, which in end view is subtriangular and the aperture terminal. They re-

semble in general d'Orbigny's species described from the Cretaceous of the Paris Basin.

Length, 0.65 millimeter; breadth, 0.45 millimeter.

Figured specimen (Cushman Coll., No. 5199).

Cristellaria gladius (Philippi)

Plate 19, Figure 7

Marginulina gladius Philippi, *Tertiär. nordwest. Deutsch.* (1843), p. 40, Pl. 1, Fig. 37.

Cristellaria gladius d'Orbigny, *Prodrome de Paléont.*, Vol. 3 (1852), p. 154.

The figured specimen is very close in its details to the form figured by Chapman from the Gault of England, and referred by him to this species.

Length, 0.75 millimeter; breadth, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5191).

Cristellaria humilis Reuss

Plate 19, Figure 8

Cristellaria humilis Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 46, Part 1, 1862 (1863), p. 65, Pl. 6, Figs. 16, 17.

This large species described by Reuss from the Cretaceous of Germany, and also recorded by Chapman from the Cretaceous of England, occurs occasionally in the Velasco shales.

Length, 0.90 millimeter; breadth, 0.35 millimeter.

Figured specimen (Cushman Coll., No. 5201).

Cristellaria sp.?

Plate 19, Figures 3*a*, *b*

The form figured is a small, uncoiled form with very much inflated chambers which perhaps might be better referred to *Marginulina*.

Length, 0.55 millimeter; breadth, 0.25 millimeter.

Figured specimen (Cushman Coll., No. 5186).

Cristellaria sp.?

Plate 19, Figure 11

There are specimens of an involute form with a slight keel, such as here figured, occurring rarely in the Valesco shale.

Length, 0.65 millimeter, breadth, 0.65 millimeter.

Figured specimen (Cushman Coll., No. 5195).

Cristellaria sp.?

Plate 19, Figures 14*a*, *b*

There is a very small species found in the Velasco which has somewhat the characteristics of *Cristellaria vortex* (Fichtel and Moll). It is, however, much smaller than recent forms of that species, and has fewer chambers. It is some-

what similar to forms figured by Von Schlicht from the Oligocene of Germany and referred to *C. vortex*. It probably will be found to be a distinct species.

Length, 0.35 millimeter; breadth, 0.35 millimeter; thickness, 0.16 millimeter.

Figured specimen (Cushman Coll., No. 5197).

Genus *Amphicoryne* Schlumberger, 1881

Amphicoryne sp.?

Plate 19, Figure 6

The peculiar form figured in which there are at least four somewhat uncoiled cristellarian chambers followed by a single nodosarian chamber has occurred very rarely in the Velasco shale. These form the chamber arrangement of the genus *Amphicoryne*. All the chambers are smooth and the sutures are very slightly depressed. The amount of material is insufficient for a specific determination.

Length, 0.65 millimeter; breadth, 0.20 millimeter.

Figured specimen (Cushman Coll., No. 5190).

Genus *Marginulina* d'Orbigny, 1826

Marginulina hamulus Chapman

Plate 19, Figures 17*a*, *b*

Marginulina hamulus Chapman, *Jour. Roy. Micr. Soc.* (1894), p. 161, Pl. 4, Figs. 13*a*, *b*.

The specimen here figured is rather close in its general form, number of chambers, and the obliquity of the sutures, to this species described by Chapman from the Cretaceous (Gault) of England.

Length, 0.75 millimeter; breadth, 0.30 millimeter; thickness, 0.16 millimeter.

Figured specimen (Cushman Coll., No. 5198).

Marginulina aspera Chapman

Plate 20, Figure 1

Marginulina aspera Chapman, *Jour. Roy. Micr. Soc.* (1894), p. 162, Pl. 4, Fig. 18.

Chapman described this species from a single specimen which was evidently the young, consisting of but two chambers. The surface in his specimen, as in ours, is covered with spinose projections scattered over the general surface and with a conspicuous neck. The original specimen of Chapman was from the Cretaceous (Gault) of England.

Length, 0.65 millimeter; breadth, 0.25 millimeter.

Figured specimen (Cushman Coll., No. 5204).

Genus *Vaginulina* d'Obrigny, 1826

Vaginulina truncata Reuss

Plate 19, Figure 5

Vaginulina truncata Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 46, Part 1, 1862 (1863), p. 47, Pl. 3, Fig. 9.

The figured specimen is a young only of a species which in later growth becomes very much larger, but retains its vaginuline character. It is one of the largest species in the Velasco shales, and has a very wide vertical range. It may be recognized by the inflated character of the chambers, with deep grooves along the suture lines. It has been recorded from the Cretaceous of Europe either as *Vaginulina* or *Cristellaria*.

Length, up to 2.00 millimeters.

Figured specimen (Cushman Coll., No. 5188).

Vaginulina sp.?

Plate 20, Figure 10

Specimens similar to that figured here, which may be referred to the genus *Vaginulina*, are found in comparatively few numbers in the Velasco shale.

Length, 0.90 millimeter; breadth, 0.25 millimeter.

Genus *Polymorphina* d'Orbigny, 1826

There are numerous forms belonging to this genus which, owing to the conditions of preservation of much of the material, are difficult to make out in full detail, especially the number and direction of the sutures. Several of these are figured and referred at least tentatively to described species.

Polymorphina tuberculata Wright

Plate 20, Figure 5

To this species are referred certain specimens which are more or less globular in shape and which have a surface ornamentation consisting of rounded tubercles scattered over the surface. Similar forms are recorded from the Cretaceous of Europe by Egger.

Length, 0.55 millimeter; breadth, 0.45 millimeter.

Figured specimen (Cushman Coll., No. 5210).

Polymorphina ampla Karrer

Plate 20, Figure 6

Such forms as that figured are very close to specimens from the Upper Cretaceous of Bavaria, referred by Egger to this species of Karrer's. The form is an elongate one, very slightly, if at all, compressed; the sutures not very distinct, especially in the earlier portion.

Length, 0.65 millimeter; breadth, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5213).

Polymorphina gutta d'Orbigny

Plate 20, Figures 7, 17

This is a rather short, cylindrical form, the initial end broadly rounded, the apertural end slightly tapering; sutures in the specimen figured are too indistinct to be shown. It has the general form of d'Orbigny's species.

Length, 0.80 millimeter; breadth, 0.38 millimeter.

Figured specimen (Cushman Coll., No. 5215).

Polymorphina gibba d'Orbigny
Plate 20, Figures 8, 15

Rounded forms similar to the one figured may be referred somewhat questionably to this species of d'Orbigny. Plate 20, Figure 15, shows a somewhat similar form in which the last-formed chamber is distinct from the others and has a somewhat angled form. Specimens with this character are not infrequent in the Velasco.

Length, 0.45 millimeter; breadth, 0.38 millimeter.

Figured specimens (Cushman Coll., Nos. 5211, 5212).

Polymorphina fusiformis Roemer
Plate 20, Figure 14

Elongate specimens, tapering at either end, are fairly common and may be referred to Roemer's species. They are not unlike specimens figured by Chapman from the Cretaceous (Gault) of England.

Length, 0.75 millimeter; breadth, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5214).

Polymorphina velascoensis Cushman, n. sp.
Plate 20, Figures 16*a*, *b*

Test elongate, fusiform in front view, in side view with the sides unequal, one side convex, the other concave, the concave side in front view with a central depression; chambers few, fairly distinct, the earlier ones somewhat limbate, not depressed; wall smooth; aperture terminal, radiate. This is a peculiarly formed species, and may represent an attached form.

Length, 0.70 millimeter; breadth, 0.25 millimeter; thickness, 0.18 millimeter.

Holotype (Cushman Coll., No. 5217).

Polymorphina sp.?
Plate 20, Figures 13*a*, *b*

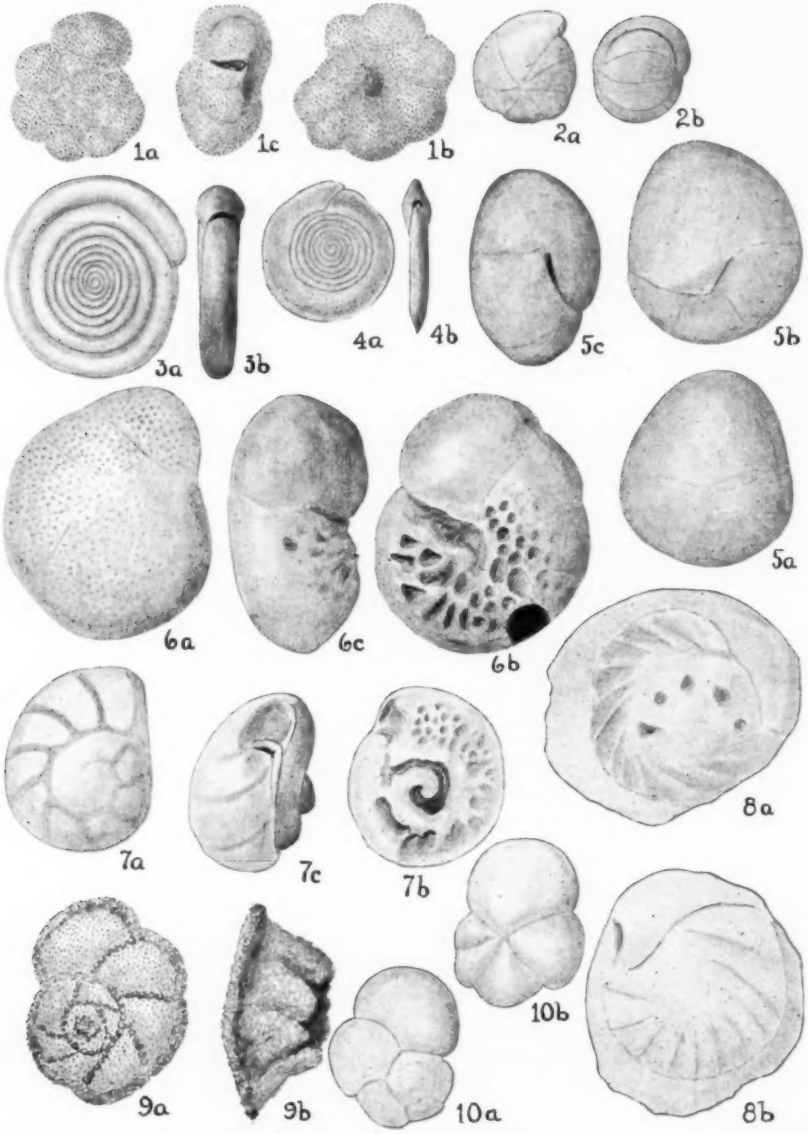
In some parts of the Velasco there are rather large specimens which are much broader than high; oval, in apertural view, similar to that here figured.

Length, 0.45 millimeter; breadth, 0.60 millimeter.

Figured specimen (Cushman Coll., No. 5216).

Family Chilostomellidae
Genus *Allomorphina* Reuss, 1849
Allomorphina velascoensis Cushman, n. sp.
Plate 20, Figures 20*a–c*

Test small, in dorsal view subtriangular, in side view broadly oval, consisting of a few chambers, three making up each coil, the chambers rapidly increasing in size as added, inflated; sutures distinct but only slightly depressed; aperture on the ventral side near the central point with a distinct overhanging lip.



FORAMINIFERA OF THE VELASCO SHALE

Length, 0.30 millimeter; breadth, 0.30 millimeter; thickness, 0.22 millimeter.

Holotype (Cushman Coll., No. 5218).

This is distinct from any of the known species of this genus, and is especially characterized by its triangular form, with a very few chambers which are smooth and fine and fairly thick.

Family Globigerinidae

Genus *Globigerina* d'Orbigny, 1826

Globigerina velascoensis Cushman

Plate 20, Figures 21*a–c*

Globigerina velascoensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 19, Pl. 3, Figs. 6*a–c*.

Test much compressed, the dorsal side with all the chambers visible, ventral side only those of the last-formed coil visible, sides nearly parallel, periphery broadly rounded; chambers distinct, three or four making up the last-formed coil, early chambers subglobular, later ones becoming more compressed, and the inner margin fairly straight; wall finely and evenly reticulate; aperture on the ventral side, elongate.

Diameter, 0.45 millimeter; thickness, 0.25 millimeter.

Holotype (Cushman Coll., No. 4348).

This is a peculiar species in its very much compressed form, the nearly straight inner margin of the chambers, and the much finer reticulate surface than usually occurs in this genus.

Globigerina cretacea d'Orbigny

Plate 21, Figures 1*a–c*

Globigerina cretacea d'Orbigny, *Mém. Soc. Géol. France*, Ser. 1, Vol. 4 (1840), p. 34, Pl. 3, Figs. 12–14.

This species is common in the Velasco shale, often occurring in great numbers. It is the commonest species of the Cretaceous of Europe and America, and much recent material has been referred to it.

Length, 0.40 millimeter; breadth, 0.40 millimeter; thickness, 0.27 millimeter.

Figured specimen (Cushman Coll., No. 5222).

Genus *Pullenia* Parker and Jones, 1862

Pullenia sphaeroides d'Orbigny

Plate 21, Figures 2*a*, *b*

Nonionina sphaeroides d'Orbigny, *Ann. Sci. Nat.*, Vol. 7 (1826), p. 293, No. 1; *Modèles*, No. 43.

Pullenia sphaeroides Parker and Jones, *Phil. Trans.*, Vol. 155 (1865), p. 368, Pl. 14, Figs. 43*a*, *b*; Pl. 17, Fig. 53.

The Cretaceous forms found in the Velasco shale and referred to this species are larger and more heavy than the Recent form also referred to this name. The

number of chambers in the fossil ones, as in that figured, show more chambers in the coil, there being as many as seven visible in the last-formed whorl, whereas in most Recent material the number of chambers is not usually more than four.

Length, 0.35 millimeter; breadth, 0.35 millimeter; thickness, 0.30 millimeter.

Figured specimen (Cushman Coll., No. 5223).

Family Rotaliidae

The Velasco shale has very many species belonging to numerous genera of the Rotaliidae, but owing to the fact that this family especially is in a very chaotic state so far as nomenclature is concerned, it has seemed best to limit the present paper to a description of those few species only which are very common in this formation.

Genus *Discorbis* Lamarck, 1804

Discorbis allomorphinoides (Reuss)

Plate 20, Figures 18*a–c*, 19*a–c;* Plate 21, Figures 5*a–c*

Valvulina allomorphinoides Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 40 (1860), p. 223, Pl. 11, Fig. 6.

The figured specimens, especially that figured, Plate 20, Figure 18*a–c*, are evidently identical with this species as described by Reuss from the Cretaceous of Central Europe. The form figured, Plate 20, Figure 19, is a somewhat smaller, less strongly developed one. The species ranges very widely in the Upper Cretaceous of Mexico and southwestern United States, occurring very often, but never, so far as seen in any considerable numbers, in a single sample.

Length, 0.45 millimeter; breadth, 0.45 millimeter; thickness, 0.35 millimeter.

Figured specimens (Cushman Coll., Nos. 5219–21).

Genus *Truncatulina* d'Orbigny, 1826

Truncatulina velascoensis Cushman

Plate 21, Figures 8*a*, *b*

Truncatulina velascoensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 20, Pl. 3, Figs. 2*a–c*.

Test nearly bilaterally symmetrical with a very thin, broad keel; chambers all visible from the dorsal side, only those in the last-formed coil from the ventral side, about ten chambers in the last-formed coil, fewer in the earlier ones; chambers distinct, especially from the ventral side; sutures on the dorsal side raised and confluent, on the ventral side slightly depressed, curved; wall smooth on the ventral side, the dorsal side with an excavated area over each chamber; aperture elongate, narrow, on the ventral side of the last-formed chamber nearly in the axis of coiling.

Length, slightly more than 0.50 millimeter; breadth, about the same; thickness, 0.30 millimeter.

Holotype (Cushman Coll., No. 4344).

This species is very distinctive in the Velasco shale by the thickened limbate sutures which become confluent on the dorsal side, leaving well-marked, depressed areas over the chambers, and by the very broad, thin keel surrounding the periphery of the test.

Genus *Anomalina* d'Orbigny, 1826

Anomalina rubiginosa Cushman, n. sp.

Plate 21, Figures 6*a–c*

Test close coiled, the dorsal side slightly convex, ventral side somewhat concave, periphery broadly rounded, nine or ten chambers in the last-formed coil, rather indistinct, as are also the sutures, more distinct in the last few chambers, dorsal side with the wall very coarsely punctate, ventral side, especially in the earlier portion, with very large depressed areas of an irregular form, giving a peculiar appearance to that portion of the test; aperture along the ventral margin of the last-formed chamber.

Length, 0.70 millimeter; breadth, 0.70 millimeter; thickness, 0.45 millimeter.

Holotype (Cushman Coll., No. 5226).

This is a fairly large species and is characterized by the peculiar indentations of the surface on the ventral side. It is fairly common in the Velasco shale, and has a rather wide range.

Anomalina velascoensis Cushman

Plate 21, Figures 7*a–c*

Anomalina velascoensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 21, Pl. 3, Figs. 3*a–c*.

Test planoconvex, the dorsal side nearly flat, ventral side very broadly rounded, periphery broadly rounded; chambers fairly distinct, eight or nine in the last-formed coil; on the dorsal side there is a depressed area coinciding with the line of coiling, the central portion raised in a spiral, later chambers with a slightly depressed area over each chamber, the sutures being somewhat limbate and raised; on the ventral side sutures limbate but not raised above the general surface, curved, in the edge view the thickenings of the dorsal side often stand up slightly above the general surface; wall generally smooth and finely punctate.

Length, about 0.50 millimeter; breadth, 0.45 millimeter; and thickness, 0.35 millimeter.

Holotype (Cushman Coll., No. 4345).

This is a widely distributed species throughout most of the Velasco formation, and may be distinguished by the very different characters of the dorsal and ventral surfaces, the peculiar spiral thickening of the dorsal side being especially marked.

Genus *Pulvinulina* Parker and Jones, 1862
Pulvinulina velascoensis Cushman
Plate 21, Figures 9*a*, *b*

Pulvinulina velascoensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 19, Pl. 3, Figs. 5*a–c*.

Test planoconvex, the dorsal side flat or even slightly concave, ventral side very much produced, periphery carinate, subacute, ventral side with the chambers very much prolonged into a distinct projecting mass, the series of which surround a depressed umbilical area; about seven chambers in the last-formed coil, distinct; sutures distinct, on the dorsal side curved, marked by a series of small, beadlike processes, the periphery of each with a slightly raised carina which marks also the line of coiling in the central portion, ventral side with the sutures nearly radiate, straight, much depressed, surface roughened with very minute, low spinose processes which rather uniformly cover the entire test; aperture elongate, narrow, on the ventral side the last-formed chamber extending from near the periphery almost to the umbilical area.

Diameter, 0.65 millimeter; thickness, 0.40 millimeter.

Holotype (Cushman Coll., No. 4347).

This is a very abundant species in the Velasco shale of this region, appearing in several forms, some of which may be worthy of distinction. It is distinguished by the very finely spinose surface, especially by the ring of projecting masses surrounding the umbilical area on the ventral side, and the ornamentation a solid, raised carina and beaded sutures.

Pulvinulina membranacea Ehrenberg
Plate 21, Figures 10*a*, *b*

One of the most common species in the Velasco shale, often forming with *Pulvinulina velascoensis* Cushman the great mass of Formanifera at certain horizons, may be referred to *P. membranacea* Ehrenberg.

Length, 0.50 millimeter; breadth, 0.40 millimeter.

Figured specimen (Cushman Coll., No. 5128).

Family Miliolidae
Genus *Cornuspira* Schultze, 1854
Cornuspira cretacea Reuss
Plate 21, Figures 3*a*, *b*

Cornuspira cretacea Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 40 (1860), p.7, 17 Pl. 1, Figs. 1*a*, *b*.

Ranging rather widely throughout the Velasco is a smooth, coiled form which probably should be referred to this species, described by Reuss from the Cretaceous of Europe.

Diameter, 0.50 millimeter; thickness, 0.15 millimeter.

Figured specimen (Cushman Coll., No. 5224).

Cornuspira bornemanni Reuss
Plate 21, Figures 4*a*, *b*

Cornuspira bornemanni Reuss, *Sitz. Akad. Wiss. Wien*, Vol. 48, Part 1, 1863 (1864), p. 39, Pl. 1, Figs. 3*a*, *b*.

Possibly to the foregoing species, which is described by Reuss from Central Europe, may be referred the form figured here, Plate 21, Figure 4. It is much compressed, the last-formed coil fairly wide, due to the involute character, the periphery somewhat keeled. Such specimens are very rare.

Diameter, 0.45 millimeter; thickness, 0.10 millimeter.

Figured specimen (Cushman Coll., No. 5225).

EXPLANATION OF PLATES

PLATE 15

FIG. 1.—*Haplophragmoides eggeri* Cushman, n. sp. *a*, dorsal view; *b*, apertural view, ×56.

FIG. 2.—*Trochamminoides velascoensis* Cushman, n. sp. *a*, dorsal view; *b*, apertural view, ×56.

FIG. 3.—*Ammodiscus pleurostomarioides* Chapman. *a*, dorsal view; *b*, ventral view; *c*, apertural view, ×56.

FIG. 4.—*Spiroplecta annectens* (Parker and Jones). *a*, apertural view; *b*, front view, ×75.

FIGS. 5, 6.—*Textularia pupa* Reuss. 5*a*, front view; 5*b*, apertural view; 6*a*, front view; 6*b*, side view, ×75.

FIG. 7.—*Textularia subglabra* Cushman, n. sp. *a*, front view; *b*, side view; *c*, apertural view, ×75.

FIG. 8.—*Textularia velascoensis* Cushman. ×75.

FIG. 9.—*Textularia excolata* Cushman, n. sp. *a*, front view; *b*, apertural view, ×75.

FIG. 10.—*Bolivina* sp.? ×100.

FIG. 11.—*Bolivina decorata* Jones. ×90.

PLATE 16

FIG. 1.—*Bolivina velascoensis* Cushman, n. sp. *a*, front view; *b*, apertural view, ×75.

FIG. 2.—*Bolivina* sp.? ×75.

FIG. 3.—*Bigenerina velascoensis* Cushman, n. sp. ×75.

FIG. 4.—*Pleurostomella velascoensis* Cushman, n. sp. *a*, front view; *b*, side view. ×75.

FIG. 5.—*Pleurostomella clavata* Cushman, n. sp. *a*, front view; *b*, side view, ×75.

FIG. 6.—*Ellipsopleurostomella curta* Cushman, n. sp. *a*, front view; *b*, side view, ×75.

FIG. 7.—*Ellipsoglandulina velascoensis* Cushman, n. sp. *a*, front view; *b*, side view. ×75.

FIG. 8.—*Gaudryina laevigata* Franke, var. *pyramidata* Cushman, n. var. *a*, front view; *b*, apertural view, ×75.

FIG. 9.—*Gaudryina velascoensis* Cushman. ×75.

FIG. 10.—*Gaudryina retusa* Cushman, n. sp. *a*, front view; *b*, apertural view. ×75.
FIG. 11.—*Gaudryina* sp.? *a*, front view; *b*, apertural view, ×75.
FIG. 12.—*Verneuilina* sp.? *a*, front view; *b*, apertural view, ×75.

PLATE 17

FIG. 1.—*Gaudryina laevigata* Franke, *a*, front view; *b*, apertural view, ×75.
FIG. 2.—*Clavulina trilatera* Cushman, n. sp. ×75.
FIG. 3.—*Clavulina trilatera* Cushman, n. sp., var. *aspera* Cushman, n. var. ×75.
FIG. 4.—*Clavulina clavata* Cushman, n. sp. ×75.
FIG. 5.—*Clavulina amorpha* Cushman, n. sp. ×75.
FIG. 6.—*Bulimina trihedra* Cushman, n. sp. *a*, front view; *b*, apertural view, ×75.
FIG. 7.—*Bulimina* cf. *inflata* Seguenza. ×75.
FIG. 8.—*Bulimina* cf. *ovata* d'Orbigny. ×100.
FIG. 9.—*Bulimina incisa* Cushman, n. sp., *a*, front view; *b*, side view, ×75.
FIG. 10.—*Lagena aspera* Reuss. ×75.
FIG. 11.—*Lagena globosa* Montagu. ×75.
FIG. 12.—*Lagena orbignyana* (Seguenza). ×75.
FIG. 13.—*Lagena orbignyana* (Seguenza), var. ×75.
FIG. 14.—*Lagena* sp.? ×75.
FIGS. 15, 16.—*Lagena marginata* d'Orbigny. ×75.
FIG. 17.—*Lagena foveolata* Reuss, var. ×75.
FIG. 18.—*Lagena quadricostulata* Reuss. ×75.
FIG. 19.—*Nodosaria soluta* (Reuss). ×75.

PLATE 18

FIG. 1.—*Nodosaria* (*Glandulina*) *cylindracea* Reuss. ×56.
FIG. 2.—*Nodosaria* cf. *adolphina* d'Orbigny. ×75.
FIG. 3.—*Nodosaria* sp.? ×75.
FIG. 4.—*Nodosaria expansa* Reuss. ×75.
FIG. 5.—*Nodosaria ambigua* Neugeboren. ×50.
FIG. 6.—*Nodosaria* sp.? ×75.
FIG. 7.—*Nodosaria limonensis* Cushman.? ×75.
FIG. 8.—*Nodosaria* (*Glandulina*) *manifesta* Reuss. ×75.
FIG. 9.—*Nodosaria soluta* (Reuss). ×75.
FIG. 10.—*Nodosaria sceptiformis* Gümbel. ×75.
FIG. 11.—*Nodosaria tenuicollis* Reuss. ×50.
FIG. 12.—*Nodosaria fontannesi* (Berthelin), var. *velascoensis* Cushman, n. var. ×50.
FIG. 13.—*Nodosaria limonensis* Cushman. ×75.
FIG. 14.—*Nodosaria limbata* d'Orbigny. ×75.
FIG. 15.—*Nodosaria praegnans* Reuss. ×75.
FIG. 16.—*Nodosaria megalopolitana* Reuss. ×50.
FIG. 17.—*Nodosaria prismatica* Reuss. ×75.

PLATE 19

FIG. 1.—*Cristellaria grata* Reuss. *a*, side view; *b*, apertural view, ×50.
FIG. 2.—*Cristellaria trunculata* Berthelin. *a*, side view; *b*, apertural view, ×50.
FIG. 3.—*Cristellaria* sp.? *a*, side view; *b*, apertural view, ×50.

FIG. 4.—*Cristellaria rotulata* Lamarck. *a*, side view; *b*, front view, ×50.
FIG. 5.—*Vaginulina truncata* Reuss. ×50.
FIG. 6.—*Amphicoryne* sp.? ×50.
FIG. 7.—*Cristellaria gladius* Philippi. ×50.
FIG. 8.—*Cristellaria humilis* Reuss. ×50.
FIG. 9.—*Cristellaria diademata* Berthelin. ×50.
FIG. 10.—*Cristellaria* cf. *lepida* Reuss. *a*, side view; *b*, front view, ×50.
FIG. 11.—*Cristellaria* sp.? ×50.
FIG. 12.—*Cristellaria* cf. *gaultina* Berthelin. ×50.
FIG. 13.—*Cristellaria schloenbachi* Reuss. ×50.
FIG. 14.—*Cristellaria* sp.? *a*, side view; *b*, front view, ×50.
FIG. 15.—*Cristellaria crepidula* (Fichtel and Moll). *a*, side view; *b*, front view, ×50.
FIG. 16.—*Cristellaria* cf. *navicula* d'Orbigny. *a*, side view; *b*, apertural view, ×50.
FIG. 17.—*Marginulina hamulus* Chapman. *a*, side view; *b*, front view, ×50.

PLATE 20

FIG. 1.—*Marginulina aspera* Chapman. ×50.
FIG. 2.—*Frondicularia* sp.? ×50.
FIG. 3.—*Frondicularia* cf. *interpunctata* (Von der Marck). ×50.
FIG. 4.—*Frondicularia* sp.? ×50.
FIG. 5.—*Polymorphina tuberculata* Wright. ×50.
FIG. 6.—*Polymorphina ampla* Karrer. ×50.
FIG. 7.—*Polymorphina gutta* d'Orbigny. ×50.
FIG. 8.—*Polymorphina gibba* d'Orbigny. ×50.
FIG. 9.—*Nodosinella velascoensis* Cushman, n. sp. *a*, front view; *b*, side view, ×50.
FIG. 10.—*Vaginulina* sp.? ×50.
FIGS. 11, 12.—*Ellipsosiphogenerina* sp.? ×50.
FIG. 13.—*Polymorphina* sp.? *a*, front view; *b*, apertural view. ×50.
FIG. 14.—*Polymorphina fusiformis* Roemer. ×50.
FIG. 15.—*Polymorphina gibba* d'Orbigny, var. ×50.
FIG. 16.—*Polymorphina velascoensis* Cushman, n. sp. *a*, front view; *b*, side view, ×50.
FIG. 17.—*Polymorphina gutta* d'Orbigny. ×50.
FIG. 18.—*Discorbis allomorphinoides* Reuss. *a*, dorsal view; *b*, ventral view; *c*, peripheral view, ×50.
FIG. 19.—*Discorbis allomorphinoides* Reuss. *a*, ventral view; *b*, peripheral view, ×50.
FIG. 20.—*Allomorphina velascoensis* Cushman, n. sp. *a*, ventral view; *b*, dorsal view; *c*, peripheral view, ×50.
FIG. 21.—*Globigerina velascoensis* Cushman, *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

PLATE 21

FIG. 1.—*Globigerina cretacea* d'Orbigny, *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
FIG. 2.—*Pullenia sphaeroides* d'Orbigny, *a*, front view; *b*, apertural view.
FIG. 3.—*Cornuspira cretacea* Reuss. *a*, front view; *b*, apertural view.
FIG. 4.—*Cornuspira bornemanni* Reuss. *a*, front view; *b*, apertural view.

FIG. 5.—*Discorbis allomorphinoides* Reuss. *a*, dorsal view; *b*, ventral view; *c* peripheral view.

FIG. 6.—*Anomalina rubiginosa* Cushman, n. sp. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

FIG. 7.—*Anomalina velascoensis* Cushman. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

FIG. 8.—*Truncatulina velascoensis* Cushman. *a*, dorsal view; *b*, ventral view.

FIG. 9.—*Pulvinulina velascoensis* Cushman. *a*, dorsal view; *b*, peripheral view.

FIG. 10.—*Pulvinulina membranacea* Ehrenberg. *a*, dorsal view; *b*, ventral view (all figures, ×50).

THE WOODBINE SAND OF TEXAS INTERPRETED AS A REGRESSIVE PHENOMENON[1]

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ABSTRACT

Evidence is presented to substantiate earlier statements of the writer that the age of the Woodbine is, for the most part at least, equivalent to the Cenomanian of Europe, and that its affinities are with the Comanchean rather than with the Gulf; that the Upper Grayson in northern Texas, except under certain conditions, is identical in time with the Buda of central Texas; that the disconformity between the Washita and the Woodbine appears to be only local; that the latter formation is regressive, as shown by impure waters, highly colored sands, gypsum and other salts, clays at the base, ripple marks, and a "bone bed" at the summit, etc.; that there is disconformity between the Woodbine and the Eagle Ford; that the "bone bed" at the top of the Woodbine is continuous into central Texas; that it is a part of the Eagle Ford transgression, and therefore referable to the latter formation; that the age of this "bone bed" in northern Texas is equivalent to the Middle Cenomanian, and in central Texas to the Middle Turonian of Europe; and that equivalents of all of the Cenomanian and the lower half of the Turonian are missing in central Texas in the region of Austin.

It is suggested that the regressive origin of the Woodbine may have an important bearing on the accumulation of its oil.

Of all the formations of the Texas Cretaceous the Woodbine has perhaps been the most often described and the most ardently discussed, so that the general characters of its lithology and paleontology are well known.

According to Hill,[2] the Woodbine consists of ferruginous argillaceous sands characterized by intense brownish discoloration and accompanied by bituminous laminated clays. It rests unconformably upon the Grayson marl and the Mainstreet limestone, and at its summit it is reported to pass, by imperceptible transition, to the bituminous clays of the Eagle Ford formation in such a way that the parting between the two is arbitrarily established by Hill at the zone of *Ostrea columbella*. These sands are presumed to bear the same

[1] The Woodbine was first interpreted as a regressive phenomenon by the writer in a publication which will appear in print about the first of April, 1926: "Etudes stratigraphiques et paléontologiques sur les terrains crétacés du Texas," Doctorat, Grenoble, France.

[2] R. T. Hill, "The Geology of the Black and Grand Prairies of Texas," *U. S. Geol. Survey, 21st Annual Report*, Part 7 (1900), p. 293. This work gives a detailed description of the Woodbine and reviews the opinions and literature up to 1900.

relation to the Upper Cretaceous that the Trinity bears to the Comanchean; that is, that they are "a part of the great basement littoral of the Upper Cretaceous," and therefore transgressive over the Comanchean series. Hill mentions, however, that they differ from the Trinity sands in that they contain a greater proportion of iron and other impurities, such that the character of the water derived from them is materially affected. He enumerates glauconite, pyrite, sodium chloride, gypsum, other mineral salts, and lignite, and calls attention to certain fossils, particularly the plants.[1]

Since Hill's classic treatise numerous writers[2] have described the Woodbine at different places, giving sections and, in one case,[3] calling attention to an unconformity at the base. However, these present only minor variations. Hill's description and interpretation have remained classic to our day.

The writer[4] interprets the Woodbine as regressive. He has shown that its affinities are with the Comanchean instead of the Gulf, that its age is equivalent to the European Cenomanian, and that it is separated from the Eagle Ford (the lower part of which, in northern Texas, is also Cenomanian) by a transgression and hiatus. A "bone bed," composed of fish teeth, vertebrae, coarse sand, and pebbles, lying at the top of the Woodbine, it has been shown, is the same as a similar bed lying at the base of the Eagle Ford in central and south Texas. This "bone bed," a part of the Eagle Ford transgression, is therefore referable to the latter formation, and is not a part of the Woodbine in which it is commonly placed. It is pointed out

[1] E. W. Berry, "The Flora of the Woodbine Sand at Arthurs Bluff, Texas," *U. S. Geol. Survey Prof. Paper No. 129 G*, 1921. This paper describes forty-three species of plants collected from the Woodbine.

[2] L. W. Stephenson, "A Contribution to the Geology of Northeastern Texas and Southern Oklahoma," *U. S. Geol. Survey Prof. Paper No. 120 H*, 1918; E. T. Dumble, "The Geology of East Texas," *University of Texas Bulletin No. 1869*, 1918; W. M. Winton and Gayle Scott, "The Geology of Johnson County," *University of Texas Bulletin No. 2229*, 1922; W. M. Winton, "The Geology of Denton County," *University of Texas Bulletin No. 2544*, 1925; F. H. Lahee, "A Comparative Study of Well Logs on the Mexia Type of Structure," *Trans. Amer. Inst. Min. Eng.*, vol. 60 (1925), p. 1329; Sidney Powers, "Interior Salt Domes of Texas," *Bulletin American Association Petroleum Geologists*, Vol. 10 (1926) No.1.

[3] Dumble, *loc. cit.*

[4] *Loc. cit.*

that the age of this basal bed of the Eagle Ford is equivalent to Cenomanian in north Texas and to Middle Turonian in the region of Austin. Sufficient evidence is also produced to show that, in most of north Texas, at least, the Upper Grayson is identical in time to the Buda of central Texas, and these beds, characterized by *Stoliczkaia dispar* d'Orb., represent the topmost zone of the Albian (Vraconnian) as known in other parts of the world.[1] In the vicinity of Austin, central Texas, where the basal "bone bed" of the Eagle Ford (correlated with Middle Turonian in time) lies immediately on top of the Buda (Vraconnian in time), the equivalents of the lower half of the Turonian and all of the Cenomanian are missing.

At the time of completion of the writer's previous paper on the Woodbine, his evidence, although sufficient to justify his conclusions, was admittedly meager. This paper is supported by extended field and laboratory observations. The field work has included study at numerous localities in Fannin (notably at Hyatts Bluff), Grayson (particularly in the vicinity of Cedar Mills), Denton, Tarrant, and Johnson counties, and the contact of the Buda and Eagle Ford as far south as Austin. The writer also has recently visited the Woodbine elevated by the Palestine salt dome, Anderson County. Valued aid has come in a number of conferences with W. M. Winton, who has done extended field work in north and central Texas. A series of diamond drill cores taken under the direction of Winton in the development of the Tarrant County water conservation program and now stored in the museum of Texas Christian University have also been a source of interesting and fruitful study in connection with the problem under discussion. On the other hand, it has been impossible to consult the wealth of data which must be in the hands of the numerous oil companies operating in the region.

There are a number of features in the Woodbine, particularly in

[1] The equivalency of the Buda and Upper Grayson was first advanced by Winton and Scott, *loc. cit.* p. 31. Later R. T. Hill, without, apparently, having seen the foregoing publication, expressed himself similarly: "Further Contributions to the Knowledge of the Cretaceous of Texas and Northern Mexico," *Bull. Geol. Soc. Amer.*, Vol. 34 (1923), pp. 72 and 73. The statement that the Upper Grayson and the Buda are the same in time is strictly true for the greater part of north Texas, but, as we shall see, is slightly modified for the region on the Red River, where in places the Lower Woodbine seems to be the equivalent of the Grayson in time. Woodbine time is in no way represented at Austin.

the lower part, which the writer does not pretend to understand, and no small amount of data is waiting to be assimilated and interpreted. All of the results of his observations, however, confirm in an unquestionable manner the interpretation of the Woodbine as a regressive deposit. The following characters of the Woodbine, some of which are new observations, but most of which are well known, have led to the conclusion that the formation is regressive in origin.

1. It is agreed by all that the base of the Woodbine is composed of a dark bituminous clay, a type of deposit which would be highly improbable if the formation were transgressive. The thickness of this basal clay is not known, and appears to be exceedingly variable. It is of sufficient thickness to be exploited in the manufacture of brick at Denton, Texas. That this clayey base is continuous over large areas is proven by numerous recorded observations, and the cores of test holes driven in the Woodbine of Tarrant County, in the water-conservation development, show that the drill passed from surface sands to more and more clayey deposits, entering finally, with no indication of a sedimentary break, the clays, limestones, and marls of the Upper Washita beds.

A number of fossils, all indeterminate specifically, have been picked from some of the cores, and show, particularly in the case of the ammonites, a marked Washita complexion.

Hill and Dumble have noted that in certain places, specifically, in the vicinity of Cedar Mills, the Woodbine lies on the Mainstreet, the Grayson being absent. The writer has recently visited these localities and adds his testimony to the accuracy of these observations, but even here the basal Woodbine beds are clay. However, these geologists interpreted the conditions described as indicating erosional unconformity, while to the writer they simply mean that in this region the regressive movement of the sea had already commenced at the end of Mainstreet time.[1]

[1] It appears that in these northwesternmost parts the erosion has probably spared more of the sediments than elsewhere. The Mainstreet at this point is not more than 6 or 7 feet thick, and is underlain by the Pawpaw, which is here a cross-bedded sand. At Denison the Mainstreet is about 12 to 15 feet thick. It is probable that Cedar Mills is located almost exactly on the old shore of the Texas Comanchean embayment. The significance of these thicknesses and lithologic changes will receive fuller treatment in a paper now being prepared by Winton and the writer on the "History of the Region of the Preston Anticline."

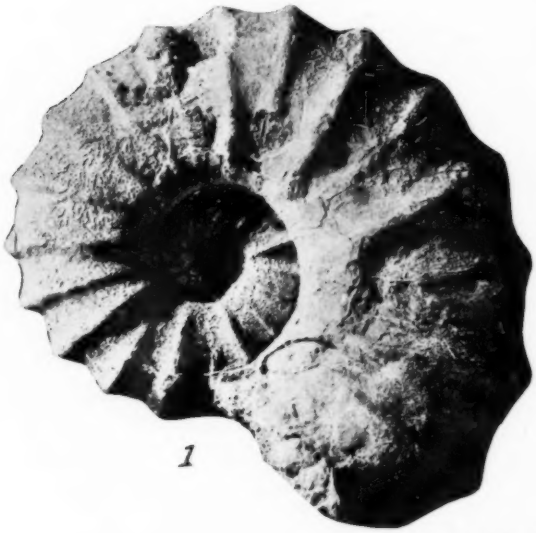

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FIG. 1.—*Acanthoceras rotomagense* de France, adult, ×½. FIG. 2.—*A. rotomagense*, small individual, natural size showing median tubercle. FIG. 3.—Ripple marks at top of Woodbine sand near Tarrant Station. FIG. 4.—Cross-bedded structure of upper part of Woodbine sand on Tarrant Station road 2 miles north of Arlington.

There is no direct fossil evidence to substantiate this view, but other facts are convincing. For example, as one goes southeast from the vicinity of Cedar Mills the Grayson appears and gradually becomes thicker. In a creek bluff at a point halfway between Pottsboro and Fink there are 15 to 25 feet of Grayson; at Denison it is 25 to 35 feet thick; across Red River, 2 miles north of Durant on the south bank of Blue River, the thickness of the formation, according to Winton,[1] is 50 feet. To the south in Denton County, at "Grayson bluff" near Argyle, the entire thickness of the Grayson is represented, including the lower or Del Rio beds and the upper limestone or Buda beds carrying an abundance of *Stoliczkaia dispar* d'Orb. The Grayson here is not less than 75 feet thick (Fig. 1).

2. Throughout the remainder of its extent the Woodbine is composed of various combinations of alternating beds of sands, sandstones, ironstones, glauconite, and clays, gypsiferous and other salt layers, and lignite beds.[2] Some of the clay layers contain masses of fossils, as, for example, a clay bed that outcrops at Hyatts Bluff,[3] on Red River in Fannin County. Through Denton and Tarrant counties a clay member near the middle of the formation has yielded a few specimens of *Acanthoceras rotomagense* (Plate 22, Figs. 1, 2). As already noted, the same Cenomanian ammonite occurs in the base of the Eagle Ford, higher up. Therefore the great gap which, in the region of Austin, includes all of the equivalents of the Cenomanian and the lower half of the Turonian is in the region of Tarrant and Denton counties, between the Woodbine and Eagle Ford, reduced to less than the thickness of the zone of *A. rotomagense*. In other words, the transgression in north Texas lies in the zone of *A. rotomagense*, and the hiatus, if indeed one exists in this region, must be very short. The assumption that the ammonites in question all belong to the same species has been questioned, but the examination of a great many individuals fails to bring out any characters

[1] Personal communication.

[2] An excellent place in which to study these characters of the Woodbine is in the section extending along the Rock Island Railroad for 2 miles east of Tarrant Station, Tarrant County. Another is along the Birdville-Arlington road, east of Birdville. These sections are described by Winton and Adkins in the "Geology of Tarrant County," *loc. cit.*

[3] Stephenson, *loc. cit.*

of specific difference between them, and although varieties may exist, there are none that cannot in all propriety be referred to some

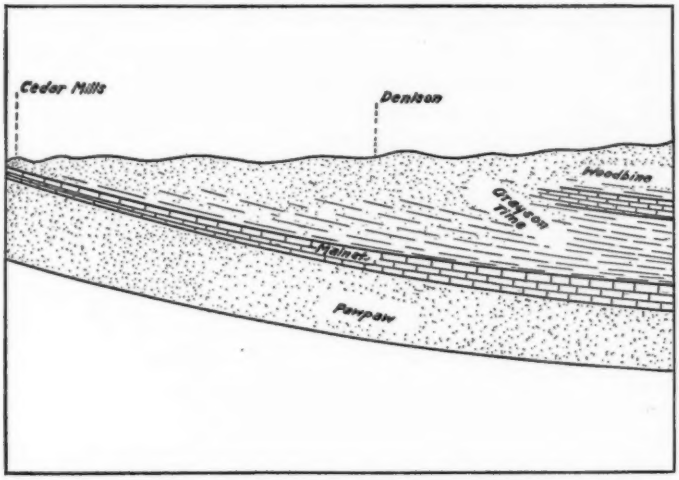

FIG. 1.—Diagram showing the lithological changes in Grayson (Del Rio and Buda) time from Cedar Mills in a southeast direction through Denison.

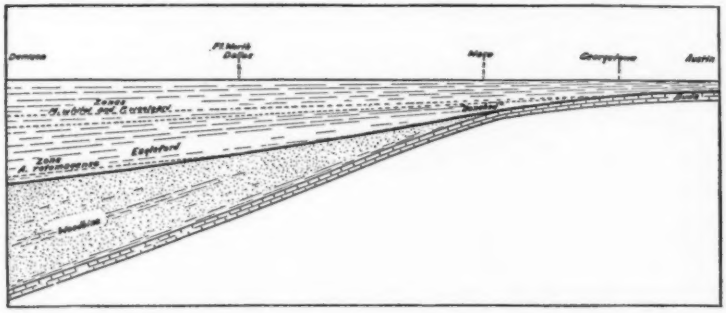

FIG. 2.—Diagram showing the relationship between the Buda, Woodbine, "bone bed," and Eagle Ford between Denison and Austin.

of the various figures in the literature of *A. rotomagense*. Specimens of different ages present marked differences.

3. The abundance of mineral salts and other impurities in the Woodbine sand heavily charges its waters, greatly affecting their potability. Such sediments must have been deposited in small lagoons and ponds left in the wake of the retreating sea. Occasionally, however, there are seams of more or less pure sand, and these, in the case of some wells, are the source of a supply of good drinking water, if only one is able to find them and case off the others. Sands worked over by a transgressing sea seldom contain many mineral salts, and their waters are usually relatively pure. These beds of the Woodbine furnishing the better grades of drinking water may represent the deposits put down during the brief advance movements of the oscillating but ever withdrawing Woodbine seas.

These facts stand out in bold relief when one compares the sands and the waters of the Woodbine with the pure waters and white beds of the well-known transgressive Trinity sands at the base of the Comanchean series.[1]

4. Beds of lignite and fossil plants disseminated at various places and levels throughout the thickness of the Woodbine, although not absolutely confirmative, also favor its regressive interpretation.

5. The extreme cross-bedding shown in the rocks at their outcrop does not exhibit the type of sorting and working over that would be characteristic of a transgressional sand. This point seems especially important in view of the fact that there seems to have been no high, nearby land mass subject to torrential erosion (Plate 22, Fig. 4).

6. At places, as, for example, near the top of the formation at the Tarrant Station locality, ripple marks are abundantly and well represented, showing that these topmost sediments were once exposed to the marginal work of the sea (Plate 22, Fig. 3).

7. These upper beds, more than any others, have been cemented into hard, resistant ledges due to the filtering in of a calcium carbonate cement, no doubt brought in by the transgressing waters at the beginning of Eagle Ford time. The same is true of the overlying "bone bed."

8. Well logs, particularly those published by Lahee,[2] show that the sandy members of the formation at Mexia are predominantly

[1] See analysis, Hill, "Black and Grand Prairies, etc., *loc. cit.*, p. 448.

[2] *Loc. cit.*

at the top. Incidentally, the mode of origin of the Woodbine sands may have an important bearing on the origin and accumulation of petroleum in the so-called "Woodbine" fields. The "fingered" arrangement of these fields is at least not contradictory. However, this question is clearly outside our problem and belongs to those who have access to more well data.

9. If the Woodbine were entirely transgressive it would seem that it ought to be represented in central Texas also. Perhaps there would not be so much of it there, but it should be present in appreciable amount. It is, in fact, inconceivable that the Upper Cretaceous transgression could have left 600 feet of transgressive sand on Red River and less than 6 inches at Austin, the latter belonging clearly to the Eagle Ford.

Some have regarded the Woodbine as a river delta, thereby explaining its great thickness on Red River. Doubtless this thickness is in part due to augmentation by river sediments, but to say that it is entirely such would preclude its deposition in a very brief period of time. As already shown, the age equivalents of the Cenomanian do not begin earlier than the Woodbine, and not more than the lower half of the Eagle Ford could, by any sort of evidence, be referred to that stage. The gap between the Woodbine and Eagle Ford, as shown elsewhere, represents at best only a very brief lapse of time. The combined thicknesses of the Woodbine and lower half of the Eagle Ford in north Texas, then, although undeniably thick, do not seem to the writer to amount to an impossible thickness for deposits of age equivalent to the European Cenomanian. In short, the writer does not believe that the great thickness of the Woodbine on Red River as compared with its total absence at Austin can be explained entirely in terms of a river delta formed at the border of an advancing sea.

It will be shown that the sea, which began to recede from all of the region of the outcrop of the Comanchean at the end of Buda (Vraconnian of Europe) time, returned at about Middle Cenomanian time in north Texas, but did not reach the region of Austin until middle Turonian time. It is to this erosional interval that the writer would attribute the complete absence of the Woodbine in the latter region; adding here the further point that at Austin the Buda shows undeniable evidence of erosion.

10. Finally, the "bone bed" (Fig. 2) lying at the base of the Eagle Ford is continuous throughout Texas from Red River to Austin, and probably elsewhere, and bears witness of a marked transgression during Eagle Ford time.

As previously indicated, this is clearly a worked-over deposit. It is made up largely of coarse sand and quartz pebbles. Sometimes these latter are of considerable size and may be picked up by the handfulls along the weathered-out exposures. Fish teeth, particularly of the pavement variety (*Pychnodus*), vertebrae, and small oysters are also abundant.[1] The writer has been able to determine the age of this "bone bed," as well as its relation to the Comanchean series, in different regions of north and central Texas with considerable accuracy by the presence of three ammonite zones in the Eagle Ford formation which in north Texas overlie this "bone bed" at intervals but which converge with it, one after the other, from Tarrant County southward to Austin.

The first of these is the zone of *Acanthoceras rotomagense*, a Cenomanian ammonite of almost world-wide distribution. A few of these have been picked up in a middle-clay member of the Woodbine, but the main zone in north Texas lies just above the "bone bed" and the ammonites are there in abundance at the Tarrant Station locality and northward. Specimens have also been collected by the staff of the geology department of Texas Christian University at this level three miles northeast of Arlington, where the Arlington-Grapevine road strikes the Eagle Ford-Woodbine contact. Farther south than this point the writer has not been able to find them, although he has made diligent search. The zone seems to be overlapped by the Eagle Ford transgression at some place between Arlington and Austin, because these ammonites have not been found at the latter point, while on the other hand, as we shall see, the upper two zones of ammonites which in north Texas occur in the upper part of the Eagle Ford are at its base in central Texas, and at Georgetown and Austin lie in direct contact with the Buda.

It has been difficult to determine the position of the upper two zones with respect to each other, due to the distance between ex-

[1] Dr. Stanton has suggested that there are any number of beds of fish teeth, vertebrae, etc. in the Eagle Ford at different levels. None of these, however, bear the coarse sand and gravel or the general appearance of the one at the base.

posures and the very uniform nature of the Eagle Ford lithology. It had seemed to the writer that the zone of *Prionotropis woolgari* is the lower of the two, but Dr. Stanton[1] has given the information that in the western interior the zone of *Metoicoceras whitei* is the lower. Quite recently W. L. Moreman, an associate of the writer, has found the zones in superposition, and it appears that in Texas also the zone of *M. whitei* is the lower of the two. The two zones, however, are never far apart, even in north Texas. They must be even closer in central Texas. In north Texas both certainly occur in the upper half of the formation.[2]

The zone of M. *whitei* Hyatt, in addition to that species, contains *M. swallovi* Shumard, *Placenticeras pseudo-placenta* var. *occidentale* Hyatt, and other forms. This zone of marvelously preserved ammonites can be found at a number of places between Sherman and Austin, the best exposure known to the writer being $2\frac{1}{2}$ miles northwest of Midlothian, on the Mansfield road. Recently, on a tributary of Burton Creek in South Austin, the writer picked up a recognizable fragment of *M. whitei* lying on the Buda limestone at the base of an Eagle Ford exposure. The specimen has been considerably worn, doubtless by the running water of the stream.

The other zone is composed of abundant but poorly preserved ammonites lying in a siliceous flaggy ledge. An ammonite from this horizon was described by Shumard[3] from 4 miles north of Sherman, Grayson County, as *Ammonites graysonensis*, and, according to Dr. Stanton,[4] is the young of either *Prionotropis woolgari* or *P. hyatti*. The writer interprets this ammonite as a young *Prionotropis woolgari*, which is a Middle Turonian ammonite having an almost world-wide distribution. It has been found in the Colorado beds of the

[1] Personal communication.

[2] These two zones were considered as one in the above-cited thesis of the writer, *loc. cit.*

[3] B. F. Shumard, "Descriptions of New Cretaceous Fossils from Texas," *Transactions St. Louis Academy of Science*, 1860. The fossil in question was later figured by C. A. White, "Contributions to Invertebrate Paleontology No. 2. Cretaceous fossils of the Western States and Territories," *Twelfth Annual Report, U. S. Geol. and Geog. Survey of the Territories* (1880), p. 39, Pl. 18, Figs. 9*a*, 9*b*.

[4] T. W. Stanton, "The Colorado Formation and Its Invertebrate Fauna," *U. S. Geol. Survey Bulletin* 106 (1893), p. 177.

western states, and has been described by Cragin from the basal complex of the Eagle Ford on San Gabriels River, 6 miles below Georgetown.[1]

The zone has been observed by the writer on the right of the Forth Worth to Dallas pike, 1 mile below the Austin Chalk escarpment and at numerous places north and south. At "blue cut," in the Santa Fe Railroad, halfway between McGregor and Moody, the zone lies at only a few feet above the Eagle Ford-Buda contact, and, as has been noted above, lies in the "bone bed" of the Eagle Ford transgression on San Gabriels River below Georgetown.

The age of the outcrop of the "bone bed" in the region of Georgetown and Austin is therefore exactly equivalent to European Middle Turonian.

To resume, the "bone bed" which in north Texas lies several hundred feet below these zones, in the zone of *Acanthoceras rotomagense*, is equivalent to Middle Cenomanian in age. At Georgetown and at Austin it is at the zones of *P. woolgari*, and *M. whitei* and is equivalent to Middle Turonian in age. Therefore, the hiatus which in north Texas is less than the thickness of the zone of *A. rotomagense* gradually increases in magnitude toward the south until it includes all of the time equivalents of the Cenomanian and the lower half of the Turonian at Austin, all of the time equivalents of both the Woodbine and lower Eagle Ford being missing in the latter region. It would appear, then, that the extreme thinness of the Eagle Ford at Austin is due to two things: one, the thinning of its constituents; the other, the absence of the lower beds (Fig. 2).

Question has been raised as to why the Woodbine is so thick on Red River whereas in central Texas it is not even represented. While at present one guess seems as good as another, the fact that the Woodbine thins uniformly from Red River southwestward while the erosion interval becomes progressively greater in the same direction leads the writer to the opinion that considerable thicknesses of sediments representing Woodbine time might have been deposited in central Texas, and that subsequent erosion, before the Eagle Ford

[1] F. W. Cragin, "A Contribution to the Invertebrate Paleontology of the Texas Cretaceous," *Geol. Survey of Texas, Fourth Annual Report* (1893), p. 243.

transgression in that region, removed them.[1] As noted above, the thickness of the Woodbine on Red River might also have been augmented by deposits of deltaic origin, possibily by a large river emptying into the Cretaceous sea in the region of what is now Red River.

The question may also be asked as to how far the sea withdrew from the land mass, and in what principal direction, during the interval between the Washita and Eagle Ford. For this question the writer has no answer. It would seem, however, that a solution to the problem may not be impossible for those who have access to logs of the many wells that must have pierced these beds at numerous places over east and central Texas.

In the meantime, however, from the facts just outlined, it becomes evident that the general idea that the Comanchean sea withdrew to the south by way of Austin cannot be maintained. In fact, the recent discovery by Powers,[2] in the upraised Cretaceous sediments around the Palestine salt dome, of about the same quality and quantity of Woodbine as found at the outcrop along Brazos River, together with the extreme thinness of that formation south of Mexia at Groesbeck, indicates that the sea could not have withdrawn to the south along a north-south line anywhere west of Palestine. It would seem then, since northeast Texas was the last region of Texas (not including west Texas) to be evacuated by the Comanchean seas, the direction of the withdrawal in that region must have been toward the southeast. Since, on the other hand, it was the first region of Texas to which the sea returned in Eagle Ford time, it must have entered from the same direction.

[1] R. T. Hill, "The Occurrence of Artesian and Other Underground Waters in Texas, New Mexico, and Indian Territory," says: "In the southern and western suburbs of Denison these sands are greatly developed. South of the Brazos River and at Austin they are entirely missing, a fact that may be explained in connection with certain changes of level which took place just after they were laid down, exposing them to erosion before the next division was deposited." From these statements it would seem that at the time, at least, Hill must not have considered the Woodbine as the basement littoral of the upper Cretaceous. There seem to be no references to this statement in his later works, and he evidently changed his views later.

[2] S. Powers, *loc. cit.*

LITHOLOGIC CHARACTER OF SHALE AS AN INDEX OF METAMORPHISM[1]

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ABSTRACT

The paper attempts to correlate the lithologic character of Cretaceous shales of the Rocky Mountain region with the degree of metamorphism to which they have been subjected, with a view of making use of the lithologic character of shale as an index of metamorphism where coals are lacking. Data presented indicate that pressure is largely responsible for the changes in the character of the shale, and that the changes may be local as well as regional in extent. The effect of the metamorphic consolidation on specific gravity, hardness, fissility, crushing strength, behavior in water, weathering, general appearance, oil and gas content of reservoirs, and kerogen in the shale is discussed.

INTRODUCTION

The fixed carbon content of coal on a pure coal basis is now generally recognized by petroleum geologists as an accurate index of the amount of metamorphism to which the coal has been subjected. Furthermore, most petroleum geologists agree that the chances of obtaining commercial production, even on very favorable structures, are small where the fixed carbon content on a pure coal basis is above 65 to 70 per cent. The details of the theory and its application to the various oil-producing regions of the United States are too well known to need any discussion here. The purpose of this paper is to discuss, in a preliminary way, the relation between the lithologic character of shales and the degree of their metamorphism, with a view to making use of these characteristics as an index of metamorphism where coals are lacking.

The data presented herewith were obtained on Cretaceous shale in the Rocky Mountain region, and it is not improbable that shales in other areas and other formations may have different properties, so that the pronounced lithification described in this paper may come at higher or lower points in the scale of metamorphism. However, from observations by the writer, it is believed improbable that there will be a great difference in the point at which it will come. Refer-

[1] Published by permission of the Midwest Refining Company, Denver, Colorado.

ence to percentages of fixed carbon mentioned in this paper indicate a pure coal basis.

STAGE OF METAMORPHISM RESULTING IN CONSOLIDATION OF SHALE

Just as the metamorphism of a coal is indicated by a progressive devolatilization, so the metamorphism of a shale is indicated by a progressive consolidation and lithification. This process starts when the constituents are laid down as a semifluid mud and may continue until the shale is altered to a schist. Between these extremes in the scale of metamorphism are many intermediate stages, and this study has been directed toward these intermediate stages and toward a search for a definite change at a stage of metamorphism equivalent to 65 to 70 per cent fixed carbon. In studying the effects of incipient metamorphism on the Cretaceous shales of the Rocky Mountain region it was found that a very marked lithification of shales normally not indurated occurs at a point in the scale of metamorphism corresponding to about 60 per cent fixed carbon.

NATURE OF METAMORPHISM OF SHALES

The consolidation of shale results in changes in the general appearance, the specific gravity, and other physical properties, the resistance to weathering and disintegration, and the composition of relatively unstable substances in the rocks.

The metamorphism which causes devolatilization of coal and consolidation of shale is believed to be largely due to pressure rather than to heat. For example, analysis of coal from the Gypsy Oil Company's Maire No. 1 on Grand Junction dome, Colorado, showed a fixed carbon content of 64 per cent, yet pyrobitumens decomposing at about 400° F., atmospheric pressure, were unaltered. And further, the fact that in destructive distillation most coals decompose at about 500° F., with the formation of gas, tar, and oil, but that in metamorphism to higher fixed carbon content they devolatilize rather than break down to oil and tar, also indicates that no very high temperatures are reached and that the process is largely the result of pressure.

The incipient metamorphism which causes the pronounced

lithification discussed in this paper is not always regional in character. Apparently it is often confined to the zone of compression in an anticline below the neutral plane of folding, or to the zone of compression near the walls of faults. However, many steeply folded anticlines show no evidence of this metamorphism. The criteria for recognizing the type of structure in which metamorphism may exist are not yet known, but it is believed that the position of the neutral plane of folding, the depth of burial, and the direction and inclination of the forces causing folding may cause large differences in the actual compression to which the beds in an anticline are subjected.

TABLE I

CHANGES IN SPECIFIC GRAVITY OF SHALE DUE TO METAMORPHISM

STAGE OF METAMORPHISM	CHANGE IN THE SPECIFIC GRAVITY		EQUIVALENT FIXED CARBON CONTENT ON PURE COAL BASIS
	From	To	
Deposition as a silt	.....	1.25	Below 50%
Consolidation to compact mud under influence of gravity and wave action	1.25	1.80	Below 50%
Consolidation to dry clay during deeper burial	1.65	2.25	Below 50%
Consolidation during dynamic movements; bedding planes accentuated and fissility developed	2.00	2.40	50–60%
Consolidation during more pronounced dynamic movements accompanied by lithification herewith described	2.25	2.65	Above 60%
Metamorphism to phyllite and schist	2.50	2.90	Above 95%

EFFECT OF METAMORPHIC CONSOLIDATION ON SOME PROPERTIES OF SHALE

The effects of the metamorphic consolidation on some properties of shales are discussed below. It will be noted that certain properties serve as reliable indicators of the degree of metamorphism, whereas others do not.

Specific gravity.—As pressure is applied to a shale it gradually becomes denser, with increase in specific gravity. The stages in the metamorphism of shale with relation to specific gravity are believed to be, roughly, as shown in Table I.

In the Crested Butte coal field, Colorado, a series of shales was collected adjacent to coal beds varying in fixed carbon content from 51 to 94 per cent. The specific gravity of the shales ranged from 2.375

to 2.592, with the shales of higher specific gravity generally associated with the coals containing the larger amounts of fixed carbon. However, the exceptions to this rule were so numerous that the specific gravity of shale is probably not a safe criterion of the amount of metamorphism, even when comparisons are made at the same stratigraphic horizon.

Hardness.—There is a saying among the anthracite miners of the Crested Butte field, Colorado, that "The harder the rock, the better the coal." Since this field is a region where coals range from 51 to 95 per cent fixed carbon within a few miles, there is an excellent opportunity for observation of the relation between hardness of shale and grade of coal. The miners' axiom gives an idea of how apparent this relationship really is. The shales associated with coals containing more than 60 per cent fixed carbon have a hardness of about 3, whereas the shales associated with coals of lower grade have a hardness of from 1 to 2.

Fissility.—Fissility is usually developed in shales some time before pronounced lithification occurs. Most of the shales in the Cretaceous rocks of the Rocky Mountain region show pronounced fissility even in the least disturbed areas, and it is probable that this character develops during the first dynamic movements to which the shale is subjected. Mr. Paul Weaver, of the Mexican Eagle Oil Company, informs the writer that in some areas of Cenozoic rocks of Southern Mexico fissility is developed only in the vicinity of folds, whereas in unfolded or undisturbed areas the shales are so massive that the taking of dips is difficult or impossible.

Crushing strength.—Crushing-strength tests on the samples of shale collected from the Crested Butte area were made by Professor Herbert J. Gilkey, of the Civil Engineering Department, University of Colorado. The results of these tests, together with the fixed carbon content of the associated coals, are given in Table II.

The relationship between crushing strength of shale and the fixed carbon content of the associated coals is indicated by these data. At the time of the writer's visit to the Crested Butte area no shale suitable for crushing-strength tests could be found adjacent to coal beds of lower fixed carbon content.

It is believed that the point in the metamorphic scale where the

shale becomes hard and no longer friable is equivalent to about 60 per cent carbon in the carbon ratio scale. Hard shales with high crushing strength have been found in the following domes or structures: Grand Junction, Carbonera, and Beaver Creek, Colorado; Clay Basin, Utah; Baxter Basin, Wyoming; and, to a lesser extent, at Cisco, Utah, and Cat Creek, Montana. At Grand Junction dome the fixed carbon content of the coal in the Dakota formation found in the Gypsy Oil Company's Maire No. 1 well at a depth of 2,505 to 2,535 feet was 63.6 per cent. In the Carbonera dome the coal in the Dakota in the Midwest Refining Company's Hayden No. 1 well at a depth of 3,182 to 3,212 feet analyzed 62.6 per cent fixed carbon. From these two cases it is evident that the hardening comes before

TABLE II

CRUSHING STRENGTH OF CRETACEOUS SHALE SAMPLES

Sample Number	Mine	Crushing Strength (Pounds per Square Inch)	Fixed Carbon Content of the Adjacent Coals
4	Crested Butte	8,480*	63.0
5	Horace	8,860	92.6
1	Elk Mountain	9,300	92.7
2	Elk Mountain	9,990*	94.3

* Average of two samples.

the coal is metamorphosed to 62.6 per cent fixed carbon. From other observations it is evident that the hardening does not take place until after the coal has a fixed carbon content of more than 58 per cent.

Most thin pieces of Mancos shale can be broken between the fingers without difficulty. However, in the case of these shales which have become lithified through this incipient metamorphism, a piece of shale one inch square and one-eighth inch thick can be broken between the fingers only with some difficulty.

Behavior in water.—Most of the non-limy, non-sandy, Cretaceous shales of the Rocky Mountain region, when placed in water, disintegrate into a mud and do not retain their original shape. When metamorphism equivalent to 60 per cent fixed carbon in the carbon ratio scale has acted upon these shales they do not disintegrate to a mud in water, but either retain their shape or crack due to a slacking

action. When stirred, the water containing the metamorphosed shale does not become muddy, as in the case of the unmetamorphosed shale. This property of the metamorphosed shales is the most easily discernible of all. It is readily apparent to the micropaleontologist when washing samples for concentration of the Foraminifera, for there is an almost complete loss of plasticity. If plasticity is a function of the colloidal content, then the state of metamorphism may be indicated by the change in colloidal content.

Behavior under weathering.—The metamorphosed shales do not weather as rapidly as those which have not been metamorphosed. This is noticeable on the outcrop where the shales may make ridges. Given a sufficiently long period of time, the shales may weather and the shales at the outcrop may be much more plastic and softer than the unweathered shales beneath. For this reason it is advisable to have samples from wells or from deep pits.

Change in appearance.—The Cretaceous shales of the Rocky Mountain region commonly have a dull drab appearance. When the metamorphism is sufficient to change coal to a 60 per cent fixed carbon content the shales take on a somewhat vitreous, shiny appearance that is difficult to describe, but recognizable by a geologist who has worked with the shales enough to become familiar with their properties.

Effect upon oil and gas.—Since the hardening here discussed occurs when the shales have been subjected to a metamorphism equivalent to 60 per cent fixed carbon in the carbon ratio scale, it is not impossible to find oil in structures which have hardened shales. The results of drilling folds containing hardened shales are as follows:

RESULTS OF DRILLING ON FOLDS CONTAINING HARDENED SHALES

Grand Junction, Colorado	Gas
Carbonera, Colorado	Gas
Beaver Creek, Colorado	Water
Baxter Basin, Wyoming	Gas
Clay Basin, Utah	Test not complete
Cat Creek, Montana	Small field of high-grade oil
Cisco, Utah	Gas

In both Cat Creek, Montana, and Cisco, Utah, the shales do not show as great an amount of hardening as in the other structures.

Three general hypotheses may be advanced to explain the absence of oil in metamorphosed folds. They are: (1) Metamorphism of the source rocks with destruction of the source material; (2) metamorphism of the reservoir rocks with decrease in porosities and prevention of migration; and (3) destruction of the oil as such. The writer is inclined to believe that the last two factors have been the most important, but the nature of this paper does not make a discussion of this point advisable.

TABLE III

COMPOSITION OF GASES FROM FOLDS CONTAINING HARDENED SHALES

Constituents	A*	B†	C‡
Methane	81.1	53.3	86.7
Ethane	6.4	3.8	5.6
Carbon dioxide	9.7	30.6	0.1
Nitrogen	2.8	12.3	7.6

* Grand Junction, Colorado, Gypsy-Maire No. 1, SE. ¼, Sec. 9, T.9 S., R. 101 W., 6th P.M.; depth, 2,585–2,609.

† Carbonera, Colorado, Sun No. 1, Sec. 8, T. 8 S., R. 102 W., 6th P.M.; depth, 2,828.

‡ Baxter Basin, Wyoming Midwest 6X, Sec. 11, T. 17 N., R. 104 W., 6th P.M.

It is noticeable that the gas obtained from these folds has a peculiar composition, containing nitrogen, carbon dioxide, and other gases in appreciable quantities. Some of the gases found are shown in Table III.

The carbon dioxide in these cases may be due to the reaction of hydrocarbon gases with oxidizing materials. The presence of nitrogen suggests that air may have been the oxidizer. The presence of air is difficult to explain unless we assume that it was in the nature of "connate" air, originally present in minute quantities in the shale and not expelled until the hardening, or that the air was carried into the structure by meteoric waters migrating through the sands. The high concentration in some of the waters on the Carbonera fold does not favor the latter interpretation.

Effect upon kerogen.—Pyrobitumens which decompose at about 400° F. and yield oil similar to that from the Green River shale are present in the metamorphosed shales and in an undecomposed state. The pressure sufficient to metamorphose the coal to above 60 per cent fixed carbon content and cause a lithification of shale is apparently not sufficient to destroy the pyrobitumens, presumably a form of kerogen, in the shale.

APPLICATION OF THE RESULTS OF STUDY

The results presented above indicate that in an area where coals are lacking, the degree of metamorphism of a shale, as determined from a study of its characteristic properties, may serve as an index of the degree of metamorphism of the area. This paper described a change in lithology equivalent to 60 per cent fixed carbon in the carbon ratio scale of metamorphism. The writer believes that it is possible, by determining the degree of hardening, to ascertain the approximate metamorphism at points above 60 per cent fixed carbon.

Every shale has a normal hardness, crushing strength, and other properties at a given stage of metamorphism. Therefore the finding of a hard shale which will not disintegrate in water indicates metamorphism only if that shale is normally soft and does disintegrate in water where the fixed carbon content of adjacent coals is below about 60 per cent. This makes it imperative that anyone attempting to interpret the character of the shale as an index of metamorphism should be very familiar with the lithologic character of the shale over wide areas. Commonly the only person in a geological organization who is fitted to do this interpretation is the micropaleontologist who has daily contact with many samples from different areas.

As noted in the early part of this paper, in other areas the stage of pronounced lithification may come at higher or lower points in the scale of metamorphism than observed in the Cretaceous shales of the Rocky Mountain region. However, the writer believes that probably such differences will be slight.

Study of the lithologic character of the shale as an index of metamorphism may serve better to estimate the oil and gas possibilities of any structure or area. In some cases structures or areas

may be definitely condemned with but small possibilities of error. Pronounced lithification of the type described occurs in an area of Papagallos shale near Linares and Monte Morales in Northern Mexico and at numerous places in the Rocky Mountain region. In less disturbed areas the location of folded strata may sometimes be determined by the amount of fissility.

ACKNOWLEDGMENT

Thanks are due to Mr. R. C. Coffin, chief geologist of the Midwest Refining Company, for permission to publish this paper; to Dr. S. K. Loy, chief chemist of the Standard Oil Company of Indiana's refinery at Casper, Wyoming, for coal analyses; to the Colorado Iron and Fuel Company for assistance in the collection of samples at Crested Butte; to Mr. E. L. De Golyer for suggestions regarding the Crested Butte locality; and to many others for helpful suggestions.

GEOLOGICAL NOTES

OCCURRENCE OF ORDOVICIAN SEDIMENTS IN WESTERN KANSAS

The M. M. Valerius Oil and Gas Company completed and abandoned a test well, July 22, 1924, located in the southwest corner of Sec. 3, T. 13 S., R. 13 E., Russell County, Kansas. The test was abandoned at a depth of 3,810 feet.

Through the courtesy of Mr. M. M. Valerius, samples of a greenish-colored shale were obtained from a depth of 3,340 to 3,380 feet, as recorded in the log of this test.

A casual examination of the samples revealed the presence of abundant bryozoans and some brachiopods. Additional cuttings were personally collected from the greenish-colored shale and additional fossil forms collected.

The first collection of fossils obtained was submitted to Dr. J. A. Udden and E. H. Sellards of the Bureau of Economic Geology and Technology, University of Texas. Dr. J. A. Udden, in a personal communication, expressed the opinion that the fossils were Ordovician in age and suggested that the forms resembled forms present in the Maquoketa shales of Iowa.

The results of this determination were mentioned to several geologists who were at the time interested in the geology of western Kansas, especially in the geology of the concealed rocks. The interpretation at that time was considered by some as beyond the realm of possibilities. A letter dated July 24, 1924, from one geologist made the following comment on the suggestion that the greenish-colored shale was of Ordovician age.

"I cannot bring myself in line with the idea that the Valerius-Phillips test is now in beds much older than Pennsylvanian. After you have plotted the Rice county logs, and have correlated them, you will find that beneath the lime series, which ends at 3,212 in the Phillips test, there is a zone of shale in which sands are reported. Then follows what I regard as the Kansas City groups of lime, in the upper part of which, throughout the state of Kansas, you frequently encounter red shale. According to my ideas the Valerius-Phillips from the red shale reported at 3385–3390, should pass through a lime zone about 200 feet to 225 feet thick, then 50 feet more or less of shale, followed by about 200 feet of lime and shale in which would occur the Oswego lime. Then approximately 200 feet of Cherokee, which should put the test at the top of the pre-Pennsylvanian."

To determine whether the original opinion could be corroborated, the same lot of fossils and additional numbers of the same forms were submitted to Dr. T. E. Savage, professor of Paleontology, University of Illinois. From a personal communication from Dr. Savage I quote:

"The identifiable bryozoans were specimens of *Escharopora subrecta*, and one or two species of *Rhynidictya*, also fragments of *Dalmanella* and *Strophomena*. The bryozoans indicate the Decorah age for the beds from which they came. This is below the Trenton, in the Black River of the Mississippi Valley."

P. V. Roundy[1] has also independently and definitely determined the age of the material occurring at 3,335 in the Valerius-Phillips test as Ordovician, from fossils obtained at that depth.

In discussing correlations of concealed beds a new term has been injected into geologic literature. Progressive well-log correlations in areas where intensive development has taken place or where there are readily recognizable units of peculiar contrast can be used to a certain degree with perfect reliance. Progressive well-log or strip correlation with reference to the Valerius-Phillips test was misleading. The point to be made is that in areas of few wells and spaced at great distances, progressive well-log correlation must be used with rare judgment. Well-log correlations supplemented by paleontologic evidence are preferable over any extensive areas.

The determination made and the opinion expressed by Dr. T. E. Savage are of interest in that this horizon from which the fossils were obtained is referred to a definite known horizon elsewhere. It is of value to the paleogeographers.

JON A. UDDEN

March 31, 1926

[1] P. V. Roundy, "The Geology of Russell County, Kansas," *Geol. Survey of Kansas, Bulletin No. 10*, (1925), p. 93.

DISCUSSION

EARLY PENNSYLVANIAN SEDIMENTS WEST OF THE NEMAHA GRANITE RIDGE, KANSAS

I have read with interest the paper on "Early Pennsylvanian Sediments West of the Nemaha Granite Ridge, Kansas," by R. C. Moore.[1] It enunciates principles which I believe will be a great aid to a study of these sediments, and in particular I concur with the conclusion that the early Pennsylvanian of this area cannot be correlated unit for unit with the beds appearing at the outcrop in eastern Kansas.

The place of origin of the author's proposed "Welch chert" is in part, I believe, well taken. However, I think that much of these sediments may well have come from the large Ordovician land mass to the west and northwest of the Welch well, which has been demonstrated by the numerous wells drilled following the Russell oil discovery. There is here a large area, the limits of which are as yet undefined, where Ordovician is encountered directly beneath Pennsylvanian beds, with a large part of the Pennsylvanian which should correspond to the Cherokee of eastern Kansas missing. This gives conditions similar to that of the Nemaha granite ridge, but in a much wider area and probably as long from north to south. Since this land mass is in the form of a broad arch, the conditions should be much more favorable to the widespread deposition which is present than would a relatively sharp narrow fold such as the Nemaha ridge. Also it is much nearer to the area of thickest deposition of the Welch chert. While it is logical that the cherty beds close to the Nemaha ridge may well be derived from a Pennsylvanian uplift of that ridge, I believe that the Welch chert in Rice, Reno, and Ellsworth counties was derived mainly from an uplift, during Pennsylvanian times, of the Russell Arch.

A. R. DENISON

ENID, OKLAHOMA

SOME FEATURES OF RED-BED BLEACHING

Not many months ago I had an opportunity to observe phenomena very similar to those described by Mr. Gail F. Moulton in an article recently published in this *Bulletin*.[2] This was in South America, in Argentina. On the east side of the Andes Mountains, in Mendoza Province, there are numerous seepages of heavy asphaltic oil, usually associated with water that contains hydrogen

[1] This *Bulletin*, Vol. 10 (1926), pp. 205–16.

[2] Vol. 10 (1926), pp. 304–11.

sulphide. In many places the sedimentary strata are cut by dikes of rafaelite, a solid bitumen. These dikes are the fillings of ancient channels by which oil once moved upward, perhaps to flow out on the surface as seepages.

There is at least one great series of red sandstones and shales here, of Lower Cretaceous age. Wherever these red beds are cut by a rafaelite dike, they have been bleached to a grayish color in a zone on each side of the dike, the width of the bleached zone varying from a fraction of an inch to many feet. I had supposed that the bleaching was due to the reducing effect of the oil, but I can see from Mr. Moulton's results that it was more probably caused by the associated hydrogen sulphide.

While engaged in these studies in Argentina I used the presence or absence of red color in the normally red sandstone as evidence for determining whether or not they had ever contained oil where now exposed on favorable structures, and therefore as an indication as to whether or not they might contain oil where now buried on favorable structures.

F. H. LAHEE

REVIEWS AND NEW PUBLICATIONS

The Possibility of Oil in Western Ziebach County. By WILLIAM L. RUSSELL, *South Dakota Geological and Natural History Survey*, February, 1925.

A small area on the northeast flank of the Black Hills in South Dakota manifests rather extraordinary structural conditions, according to the description given by the *South Dakota Geological Survey*. The first glance at the map in this circular gives one the impression that the structural contours in some mysterious manner became animate and writhed about until they were hopelessly tangled, with detached fragments lying here and there. Closer inspection resolves them into two groups that show conditions which are roughly anticlinal. The anticlines are broken by a multitude of small faults that further complicate the complex structural conditions. Seemingly the soft shales and sands that cover the surface in the part of Ziebach County that was studied in detail twist into a fantastic design of billows and troughs which can resemble only in a general way the structure of more resistent deep-seated beds.

A feature of this report that particularly appeals to the reviewer is a discussion of criteria that distinguish slumped areas from faulted areas. Such a discussion is particularly pertinent, for slumping is very prevalent in western South Dakota and there can be no doubt that it has led to many grievously erroneous conclusions. These criteria are:

1. Between the slumped blocks and the ground which did not move there is frequently a trench or depression containing undrained hollows.

2. If the slumping is related to the present topography the slumped mass will of course have moved toward the valleys and lowlands, and if there is any marked dip it is likely to be toward the highland from which it came.

3. Between the slumped block and the bed rock there is apt to be a zone filled with soil and loose fragments, and this zone differs from a true fault breccia in the fact that some of the material is derived from the surface, and that the spaces between the fragments are often unfilled.

4. The fractures induced by slumping are much less likely to be mineralized than those produced by faulting. In this area none of the fractures produced by slumping were observed to be mineralized.

5. The gliding planes of the slump are pronounced curves, steep near the upper part of the block, flatter on the lower part. Where the horizontal motion of the slump is large compared with the vertical, as is generally the case in this area, the low-angle portion of the gliding plane is dominant. The dips of the fault planes are rarely low.

6. The folding and crumpling produced by slumping is generally on a small scale.

The existence of true faults and folds may be determined by the following criteria:

1. These structural features have no relation to the existing hills and valleys. The

dips on the limbs of anticlines and synclines, and on the monoclines produced by faulting, may be continuous across several ridges and valleys.

2. In this area the faults are generally marked in part of their course by a gorge, which sometimes forms a ridge extending several feet above the ground surface.

3. The fault planes generally dip at an angle of 45 to 70 degrees, which is steeper than the gliding planes of the larger slumps.

4. Some of the faults are hinge faults, that is, the same side is in some places thrown up, relative to the opposite side; in other places down, an occurrence which would scarcely be expected along a fracture produced by slumping.

5. There are numerous grabens bounded by normal faults dipping toward each other, and this relationship would be extremely difficult to account for by slumping.

6. If dips or fractures in the Lance or Fox Hills formations were due to slumping in Lance or Fox Hills time, the overlying beds would have a different dip, as in an angular unconformity, or the fractures would end abruptly at the unconformity. No such relations were observed in the area.

7. Where the same bed may be traced continuously across areas of faulting and folding, with no gaps large enough for valleys, there is no possibility for slumping of any age.

8. The crumpling and small faulting extend to considerable depths, as is indicated by the core of the diamond drill hole at Irish Creek, in which they extend down to 1,200 feet.

The faults in this area apparently are short, have small throw, and have no uniform direction of trend. Many of them show "reverse drag," which tilts the strata on the upthrow side of the fault sharply away from it. Mr. Russell explains this by elastic rebound following the original snapping of the strata when the first break occurred.

This phenomenon of "reverse drag" is of such common occurrence in the Rocky Mountain region that it merits a more detailed and conclusive study than apparently has thus far been given it. The explanation of reversal of direction of movement along the fault plane cannot satisfy the conditions except in exceptional instances, for commonly the "reverse drag" is actually not a true drag phenomenon, and in some instances the apparently reversed dip antedated, rather than succeeded, the break.

Mr. Russell believes the faults are tension phenomena, although they occur associated with anticlinal folds which must originate through direct or indirect compression. He mentions the well-known fact that the upper strata over the crest of an arch are under tension, and he assumes that this tension has been compensated by breaking of the beds and normal faulting to accommodate the elongation due to stretching of the strata above the arch. Such stretching, of course occurs, but faults due to tension over the crest of an anticline would presumably trend parallel to the axis of the anticline, while the faults which have been mapped in this area do not do so.

The oil possibilities in this area are admittedly speculative.

K. C. HEALD

THE ASSOCIATION ROUND TABLE

JOINT MEETING WITH THE ROCKY MOUNTAIN SECTION OF THE A.I.M.M.E. AND AMERICAN MINING CONGRESS

The Executive Committee of the Association has voted to accept an invitation of the Rocky Mountain Section of the American Institute of Mining and Metallurgical Engineers and the American Mining Congress to join with them in a meeting at Denver, Colorado, on September 20–24, 1926.

It is planned that the three societies hold separate sessions for papers of technical interest and a general session for matters of interest to all societies. The banquet and entertainment will be combined. Mr. Charles M. Rath of the Midwest Refining Company, President of the Rocky Mountain Association of Petroleum Geologists, will be general chairman for this meeting. Other members of the committee will be announced later.

In order that this meeting should not conflict in any way with the proposed fall meeting of the Association in the East, it is the desire of the Executive Committee to have papers dealing with the Rocky Mountain district, western Kansas, western Oklahoma, western Texas, and California presented at the Denver meeting.

ANNUAL MEETING FOR 1927 TO BE HELD IN TULSA

The annual meeting of the American Association of Petroleum Geologists for 1927 will be held in Tulsa, Oklahoma, March 24–26, inclusive, 1927.

The personnel of the Committee for this meeting is as follows: General, M. M. Valerius; Finance, J. H. Gardner; Program, Sidney Powers; Publicity, Luther H. White; Reception, L. G. Welch; Registration, Frank Herald; Exhibits, Frank C. Greene; Entertainment, Harry H. Nowlan; Ladies Entertainment, T. E. Weirich; Golf Tournament, A. L. Beekly; Hotels, G. C. Potter; Transportation, A. W. Duston; Banquet, L. G. Keppler.

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

WILLIAM A. BARTH has resigned his position in the valuation bureau of the Louisiana Oil Refining Corporation to accept a position in the geological department of the Arkansas Fuel Oil Company, Shreveport, Louisiana, effective May 1.

MARION H. FUNK is now geologist with the Louisiana Oil Refining Corporation, working in the Shreveport district.

C. D. FLETCHER, recently paleontologist with the Atlantic Oil Producing Company, Shreveport, Louisiana, accepted a similar position, May 1, with the Gulf Refining Company at Shreveport.

A. F. CRIDER, chief geologist for the Dixie Oil Company at Shreveport, Louisiana, attended the dedication of the new Louisiana State University at Baton Rouge, April 30 to May 2, as a delegate representing the University of Kentucky.

ANGUS MCLEOD, manager of the geological and land departments of the central division of the Roxana Petroleum Corporation at Dallas, Texas, recently spent a few days on an inspection trip in the Shreveport, Louisiana, district.

W. C. SPOONER, consulting geologist, Ardis Building, Shreveport, Louisiana, has returned from a trip of several months in Central America.

C. B. HUTSON, formerly with the Empire Gas and Fuel Corporation at Bartlesville, Oklahoma, is now paleontologist for the Humble Oil and Refining Company at Shreveport, Louisiana.

ERNEST A. OBERING, geologist with the Roxana Petroleum Corporation, has been transferred from the Wichita, Kansas, office to the Shreveport, Louisiana, district.

C. M. BENNETT, vice-president, M. E. WILSON, manager of the producing department, and L. S. HARLOWE of the valuation bureau, of the Louisiana Oil Refining Corporation at Shreveport, visited producing areas in the San Antonio district last May.

J. O. NELSON, who has been stationed in the Chicago office of the Dixie Oil Company during the past year, has returned to the Shreveport, Louisiana, office to resume geological work in the Louisiana-Arkansas district.

O. L. BRACE, geologist for the Marland Oil Company of Texas in Shreveport, Louisiana, spent part of his vacation last May in California. Mr. Brace was accompanied by Mrs. Brace and son Robert Duane.

ADOLPH E. HARTMAN, geologist of San Antonio, Texas, returned early in May from a trip to Jim Hogg County, Texas, where he checked the developments of the Randado Field. Mr. Hartman owns royalty interests in that field.

F. O. MARTIN, in charge of geological work for the Union Oil Company of California in Columbia, South America, is in Spain attending the International Geological Congress.

PAUL WEAVER, who has been associated with the Cia. Mexicana de Petroleo "El Aguila," South America (Mexican Eagle) since 1911, engaged particularly in the technology of production and drilling methods, has resigned his position with the "El Aguila," effective in the very near future, and will assume duties with the Gulf Production Company at Houston, Texas, where he expects to continue his research in petroleum technology.

O. A. CAVINS, who has been working in Northern Mexico for the Standard Oil Company of California, has recently been transferred to the Los Angeles district.

The geological department of the University of California is conducting its summer camp at the South Mountain oil field near Fillmore, Ventura County. It is under the direction of DR. N. L. TALIAFERRO.

The Seismological Laboratory of the Carnegie Institution, MR. H. O. WOOD in charge, will soon move into new quarters provided by the California Institute of Technology. The new building is located near the Annandale Country Club in the western part of Pasadena. Instruction will be given here to graduate students in Seismology at the Institute.

L. C. GLENN, of the department of Geology of Vanderbilt University, has recently visited the new extension of the Eldorado, Arkansas, oil field, and has also appeared as a scientific witness for the Pure Oil Company, in a lawsuit at Lake Charles, Louisiana, involving the character, age, and origin of Sweet Lake.

DEAN E. WINCHESTER, consulting geologist, is back at his office in Denver after a week's absence during which he made a very hurried inspection of the Texas Panhandle district. Mr. Winchester is specializing in the geology of petroleum, oil shale, and coal. He wishes to correct reports that he is connected with J. H. Clark & Co. or any other like organization, and states that the advertisements carried by that company in Amarillo papers on May 28, 1926, were published without his knowledge or consent and are grossly misleading.

RUSSELL S. KNAPPEN has resigned from Harvard University and from the United States Geological Survey in order to accept a position on the geologic staff of the Gulf Refining Company. He will be located at the company's headquarters at Pittsburgh.

Word has just been received of the death of MR. STIRLING HUNTLEY, of Pittsburgh, Pennsylvania, at the hands of bandits or robbers while engaged in geological work in Northern Mexico.

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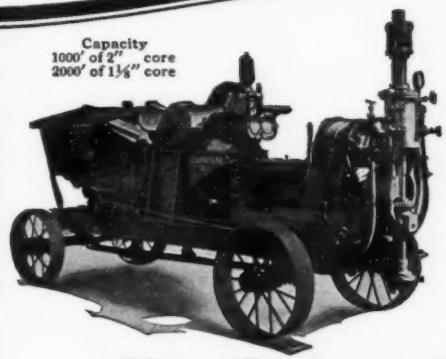

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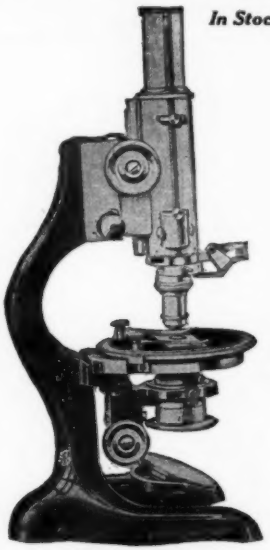

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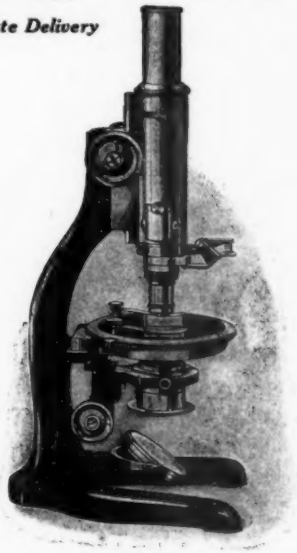

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